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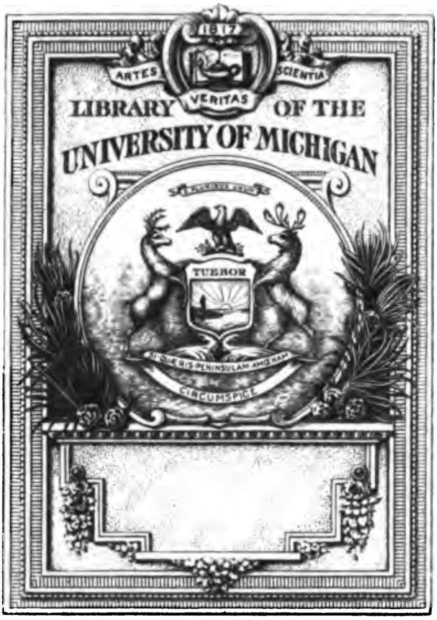
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To [illegible] M.D.
with the Childrens' Compts

AN

ESSAY

ON

Chemical Analysis:

CHIEFLY TRANSLATED FROM THE FOURTH VOLUME OF THE LAST EDITION OF THE

TRAITÉ DE CHIMIE ÉLÉMENTAIRE

OF

Louis Jacques

L. J. THENARD,

WITH ADDITIONS,

COMPREHENDING

THE LATEST DISCOVERIES AND IMPROVEMENTS IN THIS BRANCH OF THE SCIENCE.

WITH PLATES.

BY JOHN GEORGE CHILDREN,

F.R.S. L. & E. F. A.S. &c. &c.

LONDON:
PRINTED AND SOLD BY W. PHILLIPS, GEORGE YARD,
LOMBARD STREET.

1819.

g*
H.S. Jewett M.D.

TO

CHARLES HATCHETT, Esq. F.R.S.

&c. &c. &c.

Whose judgment in their guidance, has given to high talents, a direction as useful, as their possession is honourable, and to whose friendship I am proud to owe many kind services, I dedicate this Volume, a sincere, however inadequate, token of my respect, and my esteem.

JOHN GEORGE CHILDREN.

British Museum,
May 18*th*, 1819.

PREFACE.

ON reading the fourth volume of M. Thenard's "*Traité de Chimie, élémentaire, théorique et pratique,*" which treats exclusively of chemical analysis, and in a manner much more satisfactory and complete than any other work I had before met with, it struck me that if translated into our language, it could not fail to be of great utility to the English Chemist. Circumstances prevented my undertaking the task so soon as I had intended, and in the mean time, a translation was published by Mr. Merrick. As a second edition of the Traité, however, soon after appeared, I was encouraged to proceed, and I now present the following pages to the public.

A faithful translation of this part of M. Thenard's treatise, being already before the world, some apology may seem necessary, for pressing another on its attention. The important additions made by my author to his second edition, is the first I have to offer, and next, those I have taken the liberty of inserting myself. The reader who compares the present volume with the original, will find it considerably altered. I have endeavoured to omit nothing bearing on the immediate subject, and possessed of sufficient importance to claim a place, that has occurred in the science, since M. Thenard's work was published:—the new metal Cadmium, discovered by M. Stromeyer, the additional researches on Selenium, by M. Berzelius, and those on oxygenated water, by M. Thenard, may be enumerated amongst the most interesting. In some cases, as in the analysis of mineral waters, and of vegetable and animal substances, I have considerably enlarged on the original matter of my author, especially in the latter, in which, all that relates to the proximate principles is added in the present volume. The tables also, will, I hope, be found useful additions, as well as the different subjects treated of in the appendix. In respect to the proximate principles of vegetable and animal bodies, and in other instances, I have derived great assistance from the three first volumes of the Traité, and from Dr. Thomson's System of Chemistry. From the Manual of Chemistry, recently published by my friend Mr. Brande, several corrections have been introduced in the numbers stated in the tables of chemical equivalents, and on the subject of the analysis of mineral waters, I have availed myself of the valuable observations of Dr. Murray, from his papers in the Transactions of the Royal Society of Edinburgh. To Dr. Henry's Elements, I am indebted for some of the tables inserted in the appendix; nor must I omit to acknowledge my obligations to Mr. Bingley, well known as one of the most able and accurate assay masters in Europe, whose kindness in revising the fifth division of the third chapter, which treats on Cupellation, stamps no small value on that portion of the work; and to the friendship of Mr. Richard Phillips, I owe the permission to insert his admirable analysis of the Bath water. I had intended carefully to have marked every quotation I have adopted, but I found the references would be so numerous, that I determined to omit the greater part, and to acknowledge my obligations to the several authorities from whence they are taken, in this general manner, rather than weary the eye of the reader, by obliging him to turn it continually from the text to the margin, without an adequate recompense for his trouble. Where the quotations are long or important, the authorities are mentioned. Had I the leisure I once enjoyed, I might perhaps have avoided some errors, which I am conscious exist, though I hope they are not numerous, or serious. Should a second edition be hereafter called for, I shall use every endeavour to correct them.

In regard to nomenclature, I have for the most part adopted that of my author, and conceiving the accuracy of Sir Humphry Davy's views of chlorine and its compounds, to be sufficiently established, I have not hesitated to change with Thenard, *Muriatic Acid*, and the *Muriates*, into *Hydrochloric Acid*, and

Hydrochlorates, or *Chlorides*, as the case required. I am aware of the danger, I might say folly, of a passion for neology, and I disavow it; but some reformation in chemical language is imperiously called for, and we may hope the day is not far distant, when our knowledge will admit of the formation of a scientific nomenclature that shall be pure, permanent, and universal. Adopting the term *Potassa* for *Potash*, and in general, the terminations in *a* to express the oxides of the metals of the first and second sections, (see note, p. 60.) I have taken the liberty to alter *Baryta* into *Barya*, and *Strontites* into *Strontia*, as I can conceive no etymological process, by which they can respectively be derived from *Baryum* and *Strontium*, the names assigned to their bases.

The importance of chemical analysis needs no proof; it is the "mirror held up to nature," which shews the order and regularity that prevail in her minutest operations, as astronomy demonstrates their influence, in her most stupendous; it is the only basis on which chemistry can be raised to the dignity of a science; or, to sum up all in a word, it is the foundation and the force on which the atomic theory has been established, and by which it must be supported.

AN ESSAY

ON

CHEMICAL ANALYSIS.

INTRODUCTION.

IF in travelling through a country, we pay attention to the soils and rocks that occur on the way, we cannot fail to be struck with the differences they exhibit, and when the substances which the miner lays before us are examined, their almost endless variety of colour, hardness, density, and crystalline form, still more strongly excites our admiration.

If one class of bodies thus awaken our curiosity, it must be increased when we find that not only minerals, but liquids, and even aeriform substances, are far from being uniform in their characters and properties. Organized matter constitutes a third division, dissimilar from both the former, and the productions of art increase the catalogue almost *ad infinitum*. It is to chemistry that we must look for the means of satisfying the inquiries that naturally arise concerning them, and especially to that branch of it, which teaches us by what processes we may determine the nature and proportions of the elements of the various compounds, which come before us; and these processes constitute chemical analysis, properly so called.

This branch of the science, almost unknown sixty years ago, has, during that period, and particularly in the last thirty years, made great advances, from the improvements in our instruments, and the address with which they have been applied, the purity of the re-agents, the laws which have been gradually unfolded, and that accuracy, of which Lavoisier first set the example, which has since prevailed in chemical manipulation.

Heretofore, after the constituent principles of a body were known, their proportions were seldom ascertained to a tenth part; but now, the error rarely exceeds a few hundredths, except in cases where the principles are very numerous.

A general knowledge of the properties of bodies would seem, at first view, sufficient to enable any one to make an analysis, yet the inexperienced would find himself much at a loss, even in the examination of a substance containing few elements. To what tests to submit it, how to ascertain the different bodies it contains, and when ascertained, how to separate them and find the quantity of each, are so many questions, the solution of which cannot be got at without instruction in the methods to be adopted. It is evident how valuable a treatise must be, in which these are ably and accurately described. But the undertaking is one of great difficulty; the attempt, however, may be useful, though the execution be imperfect.

I shall divide this essay into seven chapters—the first will treat of the manipulations common to a great number of analyses—the second, of the analysis of gases—the third, of combustible bodies—the fourth, of oxides and acids—the fifth, of salts—the sixth, of mineral waters—and the seventh, of vegetable and animal substances.

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CHAPTER I.

Of the manipulations generally necessary in Chemical Analysis.

THERE are certain operations that continually occur, which I shall describe once for all, to avoid unnecessary repetitions.

§ 1. Before a solid body is submitted to analysis, it must be reduced to small fragments, and often to an impalpable powder. This operation is performed by means of instruments harder than the substances themselves so as not to be abraded by them, as files and mortars of Wedgewood's ware, iron, agate, &c. If the substance notwithstanding abrade the instrument used, the quantity so worn off must be ascertained, and account kept of it.

§ 2. A certain quantity of the substance, 100 grains for instance, is next to be weighed in a very accurate balance, which should be sensible to the fiftieth of a grain, when loaded with 500 grains on each side. (Appendix A.)

§ 3. The weighed portion is then to be submitted to the action of substances capable of effecting its total or partial solution, after which, different re-agents must be added, to precipitate successively, as far as possible, the various matters it contains. A large excess of precipitant should be used, provided it do not re-c solve a sensible quantity of the precipitate. Th to obtain the oxide of copper, from a solution of sulphate of that metal, more of the solution of pota than is necessary merely to saturate the acid, must poured in; otherwise, a portion of the latter woı remain united to the oxide, and the precipitate woı be a sub-sulphate, or a mixture of oxide and sı sulphate.

§ 4. The precipitate must be washed, either decanting by means of a syphon or small tube, or the filter, till the washings, which must be added the original solution, cease to carry off any matt foreign to the precipitate; thus, if sulphuric acid h been poured into a solution of nitrate of barya, order to separate this base, the insoluble sulpha must be washed till the fluid which passes throu the filter is no longer rendered turbid by nitrate barya.

§ 5. The precipitate is next to be dried by expo sure at first to a gentle heat, and when sufficient deprived of moisture to fall to powder, to a red he in a crucible, and weighed while warm. If a red he decompose it, it must be dried by steam on the filte if one has been employed, or otherwise in a glass c Wedgewood basin, stirring it from time to time; or may be placed in a vacuum by the side of a capsul containing strong sulphuric acid, or fragments c chloride of calcium (muriate of lime) recently fused If the precipitate has been collected on a filter, and b not decomposable by a high temperature, nor liabl to be affected by the matter of the filter, expose th whole at once to a red heat; the filter will be con sumed, and the precipitate alone remain in the crucible; but if the charcoal of the filter would probably reduce the precipitate, as is the case with those oxides whose bases have not a strong attraction for oxygen, first reduce it to as complete a state of dryness as can be done without scorching the filter, and ascertain its weight, next detach a portion, weigh it, heat it to redness in a crucible, and weigh it again. As the weight of the portion detached is to that of the whole quantity, so is the loss of weight it experienced by a red heat, to that which the whole would have sustained. (Appendix B.)

§ 6. In evaporating solutions to dryness, care must be taken, as soon as the matter begins to thicken, that none be spirted out of the capsule, which is effected by continually stirring the mixture, and a due regulation of the heat.

§ 7. If the subject of the analysis be liquid, the same operations, except the first, are to be performed.

§ 8. The analysis of gases requires some manipulations peculiar to elastic fluids. As the weight of these bodies is generally estimated by their volume (their specific gravity being known) we must constantly keep account of the pressure to which they are submitted, of their temperature, and even, when in contact with water, of their hygrometrical state, their volumes being affected by every change in these influences; and they must be measured also with extreme care. For this purpose we may use a graduated tube of the capacity of one cubic inch, divided into a hundred equal parts. The tube is to be filled with water or mercury, taking care that no portion of air remains attached to the sides of it; then holding it with one hand, the open extremity being immersed in the fluid, the gas is passed up into it, by means o small funnel, supported by the hand which holds t tube; with the other, bringing the jar containing t gas (whose mouth, like that of the tube, is immers in the fluid) by degrees under the funnel, and gent inclining it. When the tube contains the requisi quantity of gas, another jar is to be immersed in t bath in which the operation is performed, and wh sufficiently full of mercury or water, the tube receiv into it, and the whole removed. Lastly, holding t tube with pincers, in order not to heat it, let it ha time to acquire the temperature of the atmospher after which, making the exterior and interior surfac equal by raising or depressing the tube, so that th liquid it contains may be at the same height as that i which it is immersed, read off on the divisions o the tube the quantity of gas it contains, and immediately note down the temperature and pressure, i order to take account of them, should they vary i the course of the operation (*a*). Instead of removin the tube into a separate vessel, it is more convenien

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(*a*) It has been proved by M. M. Gay Lussac and Dalton, that al gases expand equally by equal increments of heat, that their expansio is uniform, and amounts, for every degree of temperature to $\frac{1}{480}$th o their volume at 32° Fahrenheit, and under the pressure of the atmosphere.

Gases are compressible; this was long ago proved by Boyle and Mariotte, and they established the law that their volumes are inversely as the pressure. When we measure a gas, therefore, it is necessary to bring the surface of the liquid in the inside of the tube containing the gas, to the same level as that of the liquid in which the tube is immersed, by raising or depressing the tube; or if that be impracticable, the difference must be ascertained and allowed for; for if the surfaces of the liquid in the tube and in the basin be equal, the gas is pressed by the whole weight of the atmosphere; if the interior level be higher than to have a cylindrical hole or cistern, of sufficient depth at one end of the mercurial trough, in which it may be depressed so as to bring the two surfaces to the same level, and the divisions may then be read off through a small plate of glass let into one of the sides of the trough.

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the exterior, it is pressed by the weight of the atmosphere, minus the weight required to support a column of the liquid equal to that in the tube above the external level; if the interior level be lower than the exterior, the gas is pressed by the weight of the atmosphere plus that of the column of liquid equal to the difference between the two levels. The weight and temperature of the atmosphere is continually varying: we must therefore assume a standard for each, and reduce all the quantities to those standards by calculation. In this country the barometrical pressure is usually assumed at 30 inches, and the temperature at 60° Fahrenheit.

Suppose 75 cubic inches of a gas to be confined in a tube by a column of mercury, 6 inches above the level of the mercury on the outside of the tube; the barometer standing at 29 inches and the thermometer at 35°. To reduce its quantity to the real bulk at the standard pressure and temperature, we must make the following corrections.

First to correct the inequalities of the interior and exterior level of the mercury;

As 30 : 30 — 6 (= 24) : : 7,5 : 6.

Next for Pressure, as 30 : 29 : : 6 : 5, 8.

Lastly for Temperature, $\frac{5,8}{5.80} = .01208 \times 25 = .302$; and $5.08 + .302 = 6.102 =$, the bulk at the assumed standard.

CHAPTER II.

Of the analysis of Gases.

§ 9. The number of gases at the freezing point of water is twenty-eight, namely, oxygen, hydrogen, hydruret and bihydruret of phosphorus, (*a*), arsenuretted hydrogen, telluretted hydrogen, potassuretted hydrogen, selenuretted hydrogen, hydruret and bihydruret of carbon, carbonic oxide, hydruretted carbonic oxide, carburetted azote, or cyanogen, chlorine, oxide (*b*), and deutoxide of chlorine, azote, oxide and deutoxide of azote, carbonic, chlorocarbonic, sulphurous, fluoboric, fluosilicic, hydrochloric, hydriodic acids, sulphuretted hydrogen (*c*), and ammonia.

Let us first detail their most obvious properties.

(*a*) M. Thenard calls these gases *protophosphuretted* and *perphosphuretted* hydrogen, and in like manner, he denominates the compounds of carbon and hydrogen, proto and percarburetted hydrogen gases. Dr. Thomson suggests that the terms hydroguret and bihydroguret of carbon would be more proper, since the carbon is the constant quantity: the same applies to the compounds of hydrogen with phosphorus. From the etymology of hydrogen (υδωρ γιγνομαι) it is not very easy to adopt any term which may express its simple combinations, without necessarily implying the presence of water. As a distinction, and to shorten the word, I have ventured to drop the two middle letters, and to use the term *hydruret* to denote a combination of the base of water, with another undecompounded substance.

(*b*) For brevity's sake the first degree of oxidation is termed simply *oxide*.

(*c*) M. Thenard uses the term *hydrosulphuric acid*, for this gas. I prefer the old name, as less likely to be confounded with the common sulphuric acid.

§ 10. The gases above enumerated may be arranged under the following heads.

A. *Colored Gases.*—Chlorine, oxide and deutoxide of chlorine, which have both a greenish yellow colour. Some gases are red, but this tint is owing to their containing nitrous vapour

B. *Gases which produce white vapours in the air.*—Hydrochloric, fluoboric, fluosilicic, and hydriodic acids.

C. *Inflammable Gases.*—Hydrogen, sulphuretted, arsenuretted, telluretted, and potassuretted hydrogen, hydruret and bihydruret of phosphorus, hydruret and bihydruret of carbon, carbonic oxide, hydruretted carbonic oxide, cyanogen, and selenuretted hydrogen.

D. *Gases which re-inflame an ignited taper.*—Oxygen, oxide of azote, oxide and deutoxide of chlorine.

E. *Acid Gases which redden the tincture of litmus.* Sulphurous, fluoboric, fluosilicic, hydriodic, hydrochloric, carbonic and chlorocarbonic acids; sulphuretted and telluretted hydrogen, and cyanogen, and probably selenuretted hydrogen: oxide of chlorine changes blue vegetable colours red, but afterwards destroys them.

F. *Inodorous Gases, or which have but a faint odour.*—Oxygen, azote, hydrogen, hydruret and bihydruret of carbon, carbonic acid and oxide of azote. The odour of most of the others is insupportable and often characteristic.

G. *Gases soluble in* $\frac{1}{30}$*th of their volume of water.*—Fluoboric, fluosilicic, (this gas is partly decomposed by water, and silica deposited), hydrochloric, hydriodic, and sulphurous acids, and ammonia.

H. *Gases soluble in alkaline solutions.*—All the acid gases, also sulphuretted and telluretted hydrogen, and probably selenuretted hydrogen, chlorine, oxide and deutoxide of chlorine, cyanogen and ammonia, (*a*).

I. *Alkaline Gas.*—Ammonia.

DIVISION I.

To ascertain the Nature of any Gas.

§ 11. Fill a tube with the gas, and plunge a lighted taper into it; if it inflame, it is one of the twelve mentioned above. (10 C.) three of which (sulphuretted and telluretted hydrogen, and cyanogen) are absorbed by solution of potassa, and by that property distinguished from the others.

A. *Hydruret of Phosphorus* inflames spontaneously and affords a very acid product.

B. *Potassuretted Hydrogen* is decomposed by water and converted instantly into hydrogen gas and alkali. This experiment is easily made by collecting the gas over mercury, and passing up into the tube a small quantity of water, which will become alkaline (*b*).

C. *Arsenuretted Hydrogen* has a nauseous smell, is insoluble in water, and forms a chesnut brown deposit of hydruret of arsenic on the sides of the tube in which it is burnt, and when agitated with one-fourth of its volume of chlorine, a liquor is formed, from which sulphuretted hydrogen precipitates yellow flakes.

D. *Bihydruret of Phosphorus* has a strong odour of garlic or phosphorus, and does not inflame spon-

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(*a*) It is only by its water that the solution acts on ammonia.

(*b*) According to M. Sementini, hydrogen gas surcharged with potassium, inflames spontaneously like hydruret of phosphorus.

taneously; the product of its combustion reddens tincture of litmus, and when agitated with an excess of solution of chlorine, a liquor is formed, which, by evaporation, leaves a very acid, viscid residuum.

E. *Hydrogen Gas* has no smell, or only a very faint one, and absorbs half its volume of oxygen gas. This is easily ascertained by introducing a hundred parts of the gas with an equal quantity of oxygen, into an eudiometer, passing an electrical spark through the mixture, and observing if the absorption has amounted to 150 parts (*a*).

F. *Carbonic Oxide* has a faint odour, absorbs half its volume of oxygen, and gives a volume of carbonic acid gas equal to its own, which may be ascertained in a manner similar to that just mentioned, by introducing 100 parts of carbonic oxide with 60 of oxygen into the eudiometer over mercury, passing an electrical spark through the mixture, measuring the residuum, and placing it in contact with a solution of potassa, to determine the quantity of carbonic acid and that of the oxygen in excess.

G. *Hydruret of Carbon* or *Olefiant Gas* has neither taste nor smell, burns with great splendour, and detonates very loudly with oxygen; it requires three times its volume of that gas for its complete combustion, and forms twice its volume of carbonic acid, the only other product being water; when mixed with about a volume and a half of chlorine over water, the mixture is gradually absorbed, and drops of an appa-

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(*a*) It is necessary not to use too large a quantity of the gases, and that the tube in which they are detonated be very strong, otherwise serious accidents may happen from the bursting of the eudiometer. One-fourth of a cubic inch of hydrogen and as much oxygen is sufficient, and more might be dangerous.

rently oleaginous fluid are seen floating on the surface of the water.

H. *Bihydruret of Carbon* has but a faint odour, 100 measures require for their complete combustion 200 measures of oxygen, and form 100 measures of carbonic acid; the only other product is water. We are indebted to the accuracy of Mr. Faraday's observations, for correcting a mistake that has hitherto existed respecting this gas, viz. that it is not acted on by chlorine. Bihydruret of carbon, as well as olefiant gas, *is* decomposed by chlorine. If the gas obtained by distilling acetate of potassa, or coal, or that from the decomposition of alcohol, be mixed with about twice its bulk of chlorine, and exposed in a dry close vessel to the sun's rays when bright, in a few moments they combine with explosion; otherwise a different action ensues, the vessel becomes filled with a cloud, which soon collects in drops of the same oily fluid that is formed by adding olefiant gas to chlorine, and hydrochloric acid gas is also produced. If the quantity of chlorine be not sufficient to combine with all the hydrogen liberated by the formation of the oily fluid, still the bihydruret is decomposed, and the products are the oil, which is the principal, and pure hydrogen. The sun's rays in London at three o'clock in the middle of November, were sufficiently powerful to produce the effect immediately, and in three or four days, it takes place even in the dark. (See Journal of Science, &c. vol. 6, p. 358.) The action of chlorine, therefore, must henceforth be discarded as one of the tests to distinguish the hydruret from the bihydruret of carbon, (*a*.) The greater brilliancy of

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(*a*) Dr. Henry, in the last (8th) edition of his "Elements of Experimental Chemistry," mentions chlorine in this respect. "The condenthe flame of the former, however, is a strong mark of distinction between them; but the most certain, is the difference of their specific gravities, and the unequal quantities of oxygen they require for complete combustion.

I. *Sulphuretted Hydrogen* has the smell of rotten eggs, blackens solutions of lead, deposits sulphur when burnt in a tube, and is absorbed by a solution of potassa.

K. *Telluretted Hydrogen* has a fetid odour, something like that of sulphuretted hydrogen, is absorbed by solution of potassa, is soluble in water, and the solution by exposure to the air, deposits a brown powder of hydruret of tellurium. Lastly, when agitated with solution of chlorine in excess, it forms a hydrochlorate, which gives a white precipitate with alkaline carbonates, and a black one with the hydrosulphurets.

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sation of percarburetted hydrogen by chlorine, affords an easy way of *estimating the quantity* of the former, in any mixture of it with hydrogen, *light carburetted hydrogen* and carbonic oxide gases." (Vol. I. p. 440.) I notice this passage, not with a view to detract from the merits of that excellent work, in which an immense mass of information is condensed into a comparatively small compass, with a clearness and precision seldom equalled, but to demonstrate by how minute degrees only, chemistry, as well as every other science, can hope to attain perfection. In the multitude of objects it embraces, it is impossible that any chemist, however indefatigable, should prove every fact he has occasion to mention in a general work, by his own experiments; nor if he could, is it likely that some things would not escape the keenest observation. He must take much on the authority of others, and in a manual like this before the reader, it is particularly the case. I have endeavoured to avoid gross errors, but I will not say that some such may not be found in these pages, even with all the advantages the foundation I build on affords me. I hope, however, they are few; one thing I am sure of, that when candidly pointed out, they will be gratefully corrected, should a second edition of this essay be hereafter called for.

L. *Cyanogen* has a very peculiar, strong and disagreeable odour; tincture of litmus that has been reddened by it, resumes its blue colour on being heated, and the gas, mixed with a little carbonic acid, is disengaged; it is not decomposed by a very high temperature, water at common temperature and pressure dissolves 4½ times its bulk of it. Phosphorus, sulphur, iodine, or hydrogen, when heated in cyanogen, exert no action on it, but potassium combines with the gas and forms a yellowish alkaline cyanodide, capable of decomposing water, and forming hydrocyanate of potassa, which, with solutions of peroxide of iron, gives a precipitate of Prussian blue. Lastly, when detonated with twice its volume of oxygen, the products are carbonic acid and azote.

M. *Selenuretted Hydrogen.*—Of this gas very little is at present known, except that it resembles sulphuretted hydrogen in its general characters; when a small bubble of it not larger than a pea is drawn into the nostrils it excites inflammation of the membrane, and symptoms of catarrh, which do not readily subside.

§ 12. If the gas be not inflammable, but is absorbed by a concentrated alkaline solution, it must be one of the eleven following, viz.: hydrochloric, hydriodic, fluoboric, fluosilicic, sulphurous, carbonic, chlorocarbonic, chlorine, oxide or deutoxide of chlorine, or ammonia: the hydrochloric, hydriodic, fluoboric, and fluosilicic acid gases, in consequence of their great attraction for water, produce white vapours with the air, and are by this property distinguished from all the rest; they are further identified as follows.

A. *Fluosilicic Acid Gas.*—Water separates from it white flakes of hydrate of silica.

B. *Hydriodic Acid Gas.*—Chlorine throws down iodine from this gas, and turns it violet.

C. *Hydrochloric Acid Gas* forms with solutions of nitrate of silver a white precipitate of chloride of silver, which turns black by exposure to light, is insoluble in acids, and very soluble in ammonia; and when the gas is combined with water and heated in contact with peroxide of manganese, chlorine is evolved.

D. *Fluoboric Gas* is easily known by occasioning denser vapors in the air than the other gases (*a*) and by its blackening paper immersed in the vessel containing it. The other gases are recognised with equal facility, as

E. *Chlorine* by its greenish yellow colour, a property which is only common to it and the oxides of chlorine, by its not being altered by exposure to the highest heat, by its destroying vegetable colours, and by its immediate action on mercury at common temperatures.

F. *Oxide of Chlorine* is of a greener yellow than the preceding, and has the odour of burnt sugar mixed with that of chlorine; it exerts no action on mercury at ordinary temperatures, but water absorbs eight times its volume of the gas; it is decomposed with explosion if a red hot iron or piece of ignited charcoal be introduced into the vessel containing it, five volumes of the gas becomes six, after decomposition, and consist of four volumes of chlorine and two of oxygen.

(*a*) However small a portion of water any gas may contain, a sensible formation of vapour ensues on mixing it with fluoboric acid gas; hence it becomes a very useful test to ascertain if a gas be perfectly dry.

G. *Deutoxide of Chlorine* is of a brighter yellowish green than the oxide, its smell is peculiar and aromatic, without any mixture of the odour of chlorine. Water absorbs rather less of this gas than of the preceding. It destroys moist vegetable blues, without previously reddening them. It has no action on mercury, nor on any combustible, except phosphorus, which, if introduced into the gas, occasions an explosion and burns with great brilliancy. It explodes more violently than the oxide, when heated to 212°, giving out much light. Two volumes by decomposition become three, and consist of two volumes of oxygen, and one of chlorine.

H. *Sulphurous Acid* is distinguished by its odour, which is the same as that of burning sulphur.

I. *Ammonia* by its odour also, which is pungent and quite peculiar; by its restoring the blue colour of litmus, that has been reddened by acid, by its neutralizing acids, and forming dense white vapours with those that are gaseous.

K. *Chlorocarbonic Acid* is immediately converted by a *very small* quantity of water into hydrochloric acid which remains in solution, and carbonic acid which retains its gaseous state; if zinc or antimony be heated in it, the results are a chloride and carbonic acid, and in both cases, the volume of carbonic oxide, and carbonic acid, is equal to that of the chlorocarbonic acid gas employed.

L. *Carbonic Acid Gas* is distinguished from all the other gases, absorbable by the alkalies, by being inodorous, by its scarcely reddening even every dilute tincture of litmus, and by its making lime water turbid, and throwing down from it a precipitate soluble in vinegar with effervescence.

§ 13. Suppose, lastly, that a gas be neither inflammable nor absorbed by solution of potassa; it must be either oxygen, azote, oxide of azote, or deutoxide of azote. Oxygen can only be confounded with oxide of azote; the property which both these gasses have of rekindling an ignited taper, distinguishes them from the two others. They are characterised besides,—

A. *Oxygen*, by its being tasteless, and capable of condensing twice its volume of hydrogen; and,

B. *Oxide of Azote*, by its sweetish taste, by its being soluble in a little less than half its volume of water at the average temperature and pressure, and by affording a residuum containing a large proportion of azote, when detonated with an equal volume of hydrogen over mercury.

The two others are distinguished—

C. *Deutoxide of Azote* (nitrous gas) by its being colourless, but immediately becoming red, when in contact with the atmosphere, or oxygen, and passing to the state of nitrous acid.

D. *Azote*, by its being inodorous, colourless, and tasteless, by its extinguishing burning bodies, undergoing no change from contact with the air, and not rendering lime water turbid.

SECTION THE SECOND.

To distinguish the Elements of a Gaseous Mixture.

§ 14. Certain gases, when in contact, either unite, or are decomposed by their mutual action (*a*). The following are incompatible in the same mixture:

(*a*) Potassuretted hydrogen is not taken into the account, as its existence is only momentary.

A. Oxygen, with hydruret of phosphorus, and deutoxide of azote, and under a slight pressure with bihydruret of phosphorus.

B. Hydruret of carbon, with chlorine.

C. Hydrogen, hydruret, and bihydruret of carbon, and carbonic oxide, with chlorine, when exposed to the sun's rays, and with *oxide of chlorine* probably under every possible circumstance.

D. Arsenuretted hydrogen with chlorine and oxide of chlorine.

E. Telluretted hydrogen with chlorine, oxide of chlorine, and ammonia.

F. Sulphuretted hydrogen with chlorine, oxide of chlorine, ammonia, and sulphurous acid gas; but if sulphuretted hydrogen, and sulphurous acid gas, be both very dry, they do not act on each other till after some time.

G. Hydruret of phosphorus, with oxygen, oxide of azote, chlorine, oxide of chlorine, and hydriodic acid, and perhaps sulphurous acid. Both hydruret and bihydruret of phosphorus instantly unite with hydriodic acid, and form a crystalline compound.

H. Bihydruret of phosphorus, with oxygen, oxide of chlorine, and hydriodic acid; and with oxygen under slight pressure; and perhaps sulphurous acid.

I. Oxide of azote with hydruret of phosphorus, and *perhaps* hydriodic acid and oxide of chlorine.

K. Deutoxide of azote with oxygen, and oxide of chlorine, and with chlorine when in contact with water.

L. Chlorine with hydrogen, bihydruret of carbon, and carbonic oxide, if exposed to the sun's rays; with hydruret of carbon, sulphuretted hydrogen, arsenuretted hydrogen, telluretted hydrogen, hydriodic acid, and ammonia, under any circumstances; lastly, with deutoxide of azote, and sulphurous acid gases, when in contact with water.

M. Oxide of chlorine with hydrogen, hydruret and bihydruret of carbon, bihydruret of phosphorus, sulphuretted, arsenuretted, and telluretted hydrogen, carbonic oxide, oxide of azote, hydrochloric and hydriodic acids, ammonia, sulphurous acid, containing vapour of water, and *perhaps* oxide of azote, and cyanogen.

N. Cyanogen perhaps with oxide of chlorine, or even chlorine, with the intervention of water.

O. Sulphurous acid with sulphuretted hydrogen, hydriodic acid and ammonia, nor with chlorine, nor oxide of chlorine, when these gases are in contact with water.

P. Hydrochloric acid with oxide of chlorine and ammonia.

Q. Fluoboric, fluosilicic, carbonic, and chlorocarbonic acids, with ammonia.

R. Hydriodic acid, with chlorine, oxide of chlorine, and sulphurous acid gases, and ammonia.

S. Ammonia, with chlorine, oxide of chlorine, telluretted and sulphuretted hydrogen, and all the acid gases.

§ 15. The first test, to which the mixture must be submitted, is a solution of caustic potassa; for this purpose, pass up from 100 to 200 parts into a graduated tube, filled with, and inverted over mercury; then introduce a fragment of potassa, and 10 or 12 parts of water, and agitate the whole. If no absorption ensue, it may be concluded that the mixture contains only one or more of the following gases:

Oxygen,
Hydrogen,
Hydruretted carbon,
Hydruretted phosphorus,
Arsenuretted hydrogen,
Carbonic oxide,
Hydruretted carbonic oxide,
Azote,
Oxide of azote,
Deutoxide of azote.

If, on the contrary, the whole be absorbed, the compound can only contain,

Carbonic acid,
Sulphurous acid,
Hydrochloric acid,
Chlorine,
Oxide of chlorine,
Fluoboric acid,
Hydriodic acid,
Fluosilicic acid,
Chlorocarbonic acid,
Sulphuretted hydrogen,
Telluretted hydrogen,
Cyanogen,
Ammonia.

Lastly, if the absorption be partial, the mixture must be composed of gases belonging to each series. Suppose such a case, the most complicated, and comprehending both the others.

§ 16. After the action of potassa, to remove the gases of the second series, fill several small tubes with the residual gas, and ascertain its composition, as follows :—

§ 17 Deutoxide of azote will shew if it contain oxygen gas ; and oxygen if it contain deutoxide of azote; in either case it will assume a reddish yellow tinge, and become acid. This experiment is conveniently made in a small tube filled with mercury, and containing moistened blue litmus paper.

§ 18. To ascertain the presence of oxide of azote, agitate a pretty considerable quantity of the mixture for ten or twelve minutes with one-fourth of its volume of water; then fill a large flask with this water, and adapt to it a bent tube also full of water; expose the flask to heat, and introduce the tube under a receiver full of mercury. The oxide of azote will be dissolved at the common temperature, and resume the state of gas at a higher, and may be easily distinguished by its relighting an ignited taper.

§ 19. The examination for azote is more complicated, especially when the mixture contains oxide and deutoxide of azote, hydrogen, hydruret of carbon, &c. The deutoxide must first be absorbed by agitating the mixture with sulphate of iron, and the oxide of azote by distilled water deprived of its air; the residuum must next be detonated with an excess of oxygen, in the mercurial eudiometer; the remainder treated with potassa and a little water, to absorb the carbonic acid that may have been formed, and the last residuum washed and heated with phosphorus in a small retort. If any gas now remain, it is azote, and must have existed in the mixture, unless its quantity be extremely minute, for in that case it may have arisen from air adhering to the sides of the vessel employed. It may happen also, after the action of the sulphate of iron and water, that the residuum will not detonate at all with oxygen, or the combustion be incomplete. This must necessarily be the case if the mixture contained no inflammable gas, or too little, or even if only carbonic oxide was present; but all these inconveniences may be obviated by adding about a quarter of a volume of hydrogen gas.

§ 20. The preceding experiment also shews the presence of hydruret or bihydruret of carbon, or of carbonic oxide; for if the residuum after detonation be partly absorbed by potassa, and render lime water turbid, it must contain carbonic acid, which can only be derived from the combustion of those gases. To ascertain whether it proceed from one or both of them, the oxygen, oxide, and deutoxide of azote, hydruretted phosphorus, and arsenuretted hydrogen, must previously be removed, the three first by the methods already directed (§ 16, 17), the two last by sulphur and solution of potassa. The sulphur being heated in the gases will decompose them, and sulphurets of phosphorus and arsenic, and sulphuretted hydrogen, will be formed; the alkaline solution will then absorb the latter. Suppose, for instance, that having freed the mixture from the gases just enumerated, we find the specific gravity of the remainder to be 0.9811; 100 cubic inches will weigh 29.925 grs; that we then detonate 100 measures with an excess of oxygen gas over mercury, and the result is water and carbonic acid (*a*); that the oxygen absorbed amounts to 175 measures, and 150 measures of carbonic acid gas are formed. For convenience of calculation, we will consider each measure to be equal to one cubic inch; 150 cubic inches of carbonic acid contain 19.23 grs. of carbon, which is the whole quantity contained in the mixture, the remaining 10.695 grs. must consist of oxygen and hydrogen.

Carbonic acid contains its own volume of oxygen, the 150 cubic inches therefore represent an equal bulk of that gas, which weigh 50.63 grs. but 175 measures of oxygen were absorbed, equal to 59.06 grs.; the difference, therefore, or 8.43 grs. have combined with the 10.695, to form 19.125 of water, which contain 2.25 of hydrogen.

(*a*) If azote be present, it will remain mixed with the carbonic acid and oxygen, and its proportion be easily found by absorbing the carbonic acid by potassa, and analysing the residuum like common air.

The result of the analysis gives us,

Carbon	19.23
Oxygen	8.445
Hydrogen	2.25
	29.925

Now 8.445 of oxygen require 6.418 of carbon to form 14.863 of carbonic oxide, and 2.25 of hydrogen take 12.82 of carbon to form 15.07 of hydruret of carbon.

The mixture therefore consisted of

	Grs.
59 cubic inches of carbonic oxide, equal to . . .	14.86
50 ———— hydruret of carbon	15.07
100	29.93

By the same method we may determine if a mixture contain hydrogen and hydruretted carbon, or hydrogen, hydruretted carbon, and carbonic oxide; for the quantity of oxygen would give the quantity of carbonic oxide, that of the carbon, not belonging to this gas, would give the quantity of hydruretted carbon, and the hydrogen would be represented by the remainder.

§ 21. If arsenuretted hydrogen be contained in sufficient quantity in a gaseous mixture, it is readily detected by filling a tube with the gas, and introducing a lighted taper; the sides of the tube will be covered with a chesnut brown hydruret. But if the mixture contain very little of this gas it is better (the oxygen, and oxides of azote being first removed, § 16, 17), to heat a small portion of potassium in it, in a bent tube over mercury; an arsenuret of potassium is formed, which, when placed in contact with water, affords arsenuretted hydrogen, and flakes of a chesnut brown hydruret of arsenic. The products are very distinct with only half a grain of the metal to a portion of the mixture in excess. The latter is first passed up into the tube over mercury and the potassium introduced by means of a wire into the bent part, and heated by a spirit lamp; fresh gas may be added if necessary; the potassium becomes converted into a dull brown mass, and the residual gas being suffered to escape, water is passed up into the tube.

§ 22. Bihydruret of phosphorus, when it predominates in a mixture, is easily distinguished by its smell, and by affording when burnt, a very acid fixed substance. But when a mixture contains only very little of it, we must employ potassium, and operate as in the preceding experiment; a phosphuret is formed from which water disengages bihydruret of phosphorus, which at most can only be mixed with arsenuretted hydrogen, and this not yielding an acid product by combustion, is readily distinguished from the other. They may farther be distinguished by a solution of chlorine, as stated in describing their particular characters (§ 11, A, D).

§ 23. It is difficult to prove the existence of hydrogen in a mixture unless it contain no other inflammable gas, or at least only carbonic oxide. For if it contain besides, bihydruretted phosphorus, or arsenuretted hydrogen, or hydruretted carbon, it is always possible that the hydrogen may have been united to the phosphorus, carbon, or arsenic of these gases. Suppose, that having absorbed the oxygen by phosphorus, the deutoxide of azote by sulphate of iron, and its oxide by water, an inflammable residuum be left; that by detonating 100 parts of this with 50 of oxygen in the mercurial eudiometer, 60 parts are absorbed;

that only 20 parts of oxygen disappear, and no carbonic acid is formed: we may conclude, that the mixture contains two-fifths of its volume of hydrogen, and no other inflammable gas.

§ 24. The gases of the first series being ascertained, the next thing is to distinguish those of the second, or such as are absorbed by the alkalies. If the mixture contain

A. *Sulphuretted Hydrogen*, it will have the smell of rotten eggs, or at least blacken solutions of lead.

B. *Hydriodic Acid Gas* becomes violet, by the contact of chlorine, and deposits iodine.

C. *Ammonia* has a very pungent, sharp odour, turns syrup of violets green, and turmeric paper brown, and forms dense clouds with the gaseous acids.

D. *Fluosilicic Acid Gas*, when in contact with water, lets fall flakes of fluate of silica.

E. *Chlorine* has a greenish yellow colour (*a*), turns tincture of litmus yellow; acts on mercury at common temperatures, and forms a black or grey powder of chloride of mercury. When the chloride is heated with an alkaline solution, a liquid is formed, which being super-saturated with nitric acid, gives a precipitate with nitrate of silver, insoluble in nitric acid, and very soluble in ammonia.

F. *Oxide of Chlorine* has a greenish yellow colour (see note E), and if, after being placed in contact with mercury, to absorb any chlorine it may contain, it be mixed with hydrochloric acid gas, water is formed and chlorine evolved (E).

(*a*) If the quantity of chlorine in the mixture be very small, its colour may not be perceptible. The same remark is applicable to the oxide of chlorine.

G. *Sulphurous Acid Gas* has the odour of burning sulphur, and, when brought in contact with small pieces of borax, forms a compound with it, which if heated red with charcoal, and moistened, evolves the smell of rotten eggs.

H. *Fluoboric Acid Gas* blackens slips of paper exposed to it, and produces white vapours by contact with the atmosphere. This last phenomenon is also produced by hydrochloric, hydriodic, and fluosilicic acid gases, but these do not discolour paper.

I. *Hydrochloric Acid Gas* communicates to fragments of borax, the property of forming with solution of silver, a white precipitate, soluble in ammonia, and insoluble in nitric acid (*a*).

K. *Chlorocarbonic Acid Gas*, mixed with hydrochloric acid gas, and placed in contact with mercury and borax, leaves a residuum, soluble, at least in part, in alcohol; and if the alcoholic solution be diluted with warm water, carbonic acid gas is disengaged, and it acquires the property of giving a white precipitate with nitrate of silver (*b*).

L. *Carbonic Acid Gas* is detected in the mixture, if after it has been treated with hydrochloric acid gas, mercury, borax, and alcohol, as just mentioned, a

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(*a*) Hydrochloric acid is the only gas absorbed by borax, that has the property of giving with nitrate of silver a white precipitate, soluble in ammonia and insoluble in nitric acid. This salt has no action either in chlorine, oxide of chlorine, or chlorocarbonic acid gases. It absorbs hydriodic acid gas, and then precipitates nitrate of silver; but the precipitate is insoluble in ammonia.

(*b*) The object of adding hydrochloric acid gas is to change the oxide of chlorine, which the mixture may contain, into chlorine; the mercury to absorb the chlorine; the borax to absorb the hydrochloric acid gas and the strong acids; and the alcohol to absorb the chlorocarbonic acid gas.

residuum be obtained, which forms with lime or barya water, a precipitate soluble in vinegar with effervescence, (*a*).

M. *Telluretted Hydrogen Gas*, if placed in contact successively with borax, alcohol and acetate of lead, a residuum will be left, whose odour is something like that of sulphuretted hydrogen; if it dissolve wholly or in part in an alkaline solution, which being treated with an excess of chlorine, acquires the property of forming a white precipitate with alkaline carbonates, and a black one with the hydrosulphurets, (*b*).

N. *Cyanogen, or Carburetted Azote*, if after being freed by oxide of mercury from any hydrocyanic vapour it may be supposed to contain, it impart to solutions of potassa or soda, the property of forming a blue precipitate, on the addition of sulphuric acid and sulphate of iron.

§ 25. The vapours contained in a gaseous mixture may be ascertained as follows. It contains

A. *Aqueous Vapour*; if, being free from ammonia, it give white clouds with fluoboric acid gas; and if chloride of calcium deliquesce in it.

(*a*) See, in the preceding note, the reason for treating the mixture first with hydrochloric acid gas, mercury, borax and alcohol. The process is complicated because the carbonic acid gas is supposed to be mixed with a great number of others, and especially chlorocarbonic, which by its decomposition might produce carbonic acid. Otherwise it were sufficient to treat the gaseous mixture with solution of ammonia, add lime water or hydrochlorate of lime to the liquor, and ascertain if the precipitate effervescesce with vinegar or weak hydrochloric acid.

(*b*) As telluretted hydrogen cannot exist either with chlorine, or oxide of chlorine, it is needless to treat the mixture with hydrochloric acid gas and mercury, (see note L.) The borax is to absorb the strong acids, the alcohol, the chlorocarbonic, and the acetate of lead, the sulphuretted hydrogen.

B. *Nitrous Acid Vapour*; if it have a reddish colour, or when absorbed by an alkaline solution, and evaporated to dryness, the residuum give off red vapours, by the action of sulphuric acid. Nitrous acid vapour cannot exist with sulphuretted, phosphuretted, arsenuretted, nor telluretted hydrogen, ammonia, nor sulphurous acid containing water, nor probably with hydriodic acid.

C. *Vapour of Alcohol*; if after agitation with solution of potassa or soda, a spirituous product be obtained by distillation.

D. *Vapour of Ether*; if it have the smell of ether, or when treated as for the detection of the vapour of alcohol, the first product have that odour. If both these vapours be present, the products must be received separately.

E. *Hydrocyanic Vapour*; if it produce with deutoxide of mercury, a soluble cyanide, from which sulphuretted hydrogen precipitates black sulphuret of mercury, and hydrocyanic acid remains in solution.

Other vapours may be mixed with the gases, but it is not worth while to particularize them.

When a gas is saturated with vapour its quantity may be calculated as follows. Suppose the vapour to be that of water, the volume of air (atmospheric) to be 50 cubic inches, the temperature 60° of Fahrenheit, and the barometer at 30 inches. The tension or pressure of vapour at this temperature is equal to .524 of an inch of mercury, as is directly proved by experiment, (*a*). Now the density of air being 1.000

(*a*) The mode of shewing the tension of vapours is very simple. Pour mercury into a barometer tube to within about a quarter of an inch of the top, and fill it up with the fluid whose tension is to be ascerthat of steam is .624; but 50 cubic inches of air, at the above temperature and pressure weigh 15.25 grains, therefore, at the same temperature, but under a pressure of only .524 of an inch, they will weigh but .266 grain, (vide note, No. 8,) consequently the weight of the vapour will be .624 of .266, or .165 of a grain. (For a table of the elasticity of steam at different temperatures, drawn up by Mr. Dalton, see Thomson's Chemistry, vol. I. p. 97, fifth edition.)

That gases exert no pressure on the vapours they contain, is evident from this. The tension of aqueous vapour with which air at 60° is saturated, is only equal to .55 of an inch of mercury, and it would be reduced to the liquid state by the smallest increase in the height of the column, yet the air can support a column of 30 inches. The inference is irresistible.

ARTICLE I.

§ 26. Analysis of a mixture of two gases, one contained in the following series, oxygen, hydrogen, hydruretted carbon, hydruretted phosphorus, arsenu-

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tained. Stop the end with the finger, and pass the fluid frequently backwards and forwards through the tube, by inclining it, so as to detach the air bubbles that may adhere to the sides; then holding it vertically, the open end uppermost, raise the finger, and fill the tube up again with the liquid, repeating these operations, till the air is quite got rid of. Then close the mouth very carefully with the finger, plunge it into a basin of mercury and support the tube in an upright position. From the height of the mercury in the barometer at the time of the experiment, deduct that of the mercury in the tube; the difference gives the tension of the liquid; being produced by its tendency to assume the form of vapour, and depress the volume of mercury to a certain point, which the weight of the air supports, at a mean rate, at about 30 inches.

retted hydrogen, carbonic oxide, azote, oxide and deutoxide of azote; the other, in the series comprehending sulphurous, hydrochloric, hydriodic, fluoboric, fluosilicic, carbonic, chlorocarbonic acid gases, chlorine, oxide of chlorine, sulphuretted hydrogen, telluretted hydrogen, cyanogen and ammonia.

§ 27. All the gases of the first series being insoluble in solutions of potassa and soda, and on the contrary, all those of the second being soluble in those solutions, the analysis of such a mixture presents no difficulty. A certain quantity (100 or 200 parts for instance) must be passed up into a glass tube over mercury, and a rather concentrated alkaline solution introduced, and the tube agitated so long as any perceptible absorption ensues. The residuum gives the quantity of gas belonging to the first series, and this being deducted from the whole quantity, the remainder shews how much belongs to the other series, (*a*).

§ 28. Analysis of a mixture of two gases, belonging to the first series, (§ 26).

A. *Oxygen Gas and Azote.*

This analysis is effected by absorbing the oxygen and leaving the azote free. For this purpose hydrogen or phosphorus is employed.

The analysis by hydrogen may be made either over mercury or water; the gas is introduced into the detonating eudiometer, an electrical spark passed through it, and the residuum measured, the difference

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(*a*) Should the gas of the second series be ammonia, the alkaline solution would only act on it by the water it contains; it is better therefore in that case to employ mere water in the separation of the two gases.

between this and the total quantity of gas, gives the amount of the absorption; one-third of which represents the oxygen.

Suppose the mixture of		
Oxygen gas and azote be . . .	110	= 216
Hydrogen	106	
The residuum after passing the spark . . .		96
The absorption then is		120
The oxygen ($\frac{120}{3}$) is		40

The hydrogen must be in excess, in respect to the oxygen, and the mixture explosive by the electric spark. If therefore the quantity of oxygen be not sufficient for inflammation to take place, a certain portion of that gas, of known purity, must be added, and allowed for in the calculation. The analysis by phosphorus is conducted in the following manner. Suppose atmospheric air to be the subject of the experiment. Pass up into a small bent tube, a certain quantity of the air to be examined, 100 parts for instance, and introduce into the bent part two or three grains of phosphorus, heat it gently for a few seconds by a spirit lamp, till a lambent flame descends to the surface of the mercury; then let the apparatus cool, and measure the residuum; it will be found to amount to 79 parts. This experiment may be made either over mercury or water.

B. *Oxygen and Hydrogen Gases.*

Detonation by the electric spark in the eudiometer, in the manner just stated, adding if necessary a known quantity of either gas to render its explosive, is all that is required, in the analysis of this mixture. Suppose we operate on 100 parts by volume, and after detonation, 19 parts of hydrogen be left; the 81 parts absorbed, must be formed of 54 hydrogen and 27 oxygen, (for two volumes of hydrogen condense one of oxygen) and consequently the mixture contained per cent. 27 oxygen and 73 hydrogen.

Oxygen and hydrogen gases may also be separated by phosphorus over mercury at ordinary temperatures, but if the mixture do not contain three-fourths of its volume of hydrogen, a certain portion of that gas must be added, and the sides of the tube moistened to accelerate the absorption of the oxygen, (*a*). The experiment lasts many hours, and consequently the changes in pressure and temperature that may occur during its continuance, must be noted. It is not complete till the formation of vapour entirely ceases, or more certainly, till the phosphorus is no longer luminous in the dark.

(*a*) Phosphorus combines with oxygen at lower temperatures within the range of from 41° to 81° Fahrenheit, in proportion as the density of the gas is less, and the addition of certain quantities of azote, hydrogen, or carbonic acid, to a given volume of oxygen, has the same effect as diminishing the pressure. The presence of the vapour of water is also necessary to its action. Pass common air into a receiver over mercury, and introduce a cylinder of phosphorus; let both the vessel and the phosphorus be perfectly dry; white fumes will at first appear, and the phosphorus be luminous in the dark; but these effects diminish by degrees, and in twenty-four hours will have ceased altogether. Then introduce a little water into the receiver, immediately the white vapours will reappear, and the phosphorus again become luminous, and in a short time the whole of the oxygen will be absorbed. Thenard, vol. I. page 174 and 223.

C. *Of Oxygen and one of the following Gases.*

Bihydruret of carbon, bihydruret of phosphorus, arsenuretted hydrogen, carbonic oxide, and oxide of azote.

All these analyses must be performed by means of phosphorus and azote in the manner already described. In pointing out this method it is assumed that phosphorus does not decompose any of these gases, which is perhaps not absolutely correct.

D. *Of bihydruret of Carbon and carbonic oxide Gases.*

The specific gravity of the mixture must first be ascertained: a certain quantity is then to be passed up into the mercurial eudiometer with an excess of oxygen, and after detonation the residuum measured. Next, absorb the carbonic acid that will have been formed by potassa, by which a second residuum is obtained of the superabundant oxygen, which being deducted from the first, the difference is the quantity of acid gas. An example will illustrate this analysis. Let the temperature be 60° Fahrenheit.

Atmospheric pressure equal to 30 inches of mercury.

Specific gravity of atmospheric air . . .	1.000
———————— oxygen gas	1.106
———————— carbonic acid gas . . .	1.526
———————— the mixture	0.856

	grains
Quantity of mixture operated on, one cubic inch, or	.2675
Oxygen added, 1½ cubic inch	.5062
Carbonic acid formed, 1.003 cubic inch . .	.4570

Excess of oxygen, .6319 cubic inch, therefore, oxygen absorbed .8681, cubic inch . . .2930

The carbonic acid contains all the carbon of the mixture 1286

Therefore the remainder (.2675—.1286) must be oxygen and hydrogen 1389

5.7 of carbon require 15 of oxygen to form carbonic acid; therefore, .1286 require .3384 but only .2930 of the oxygen which was added have been absorbed; .0454 parts therefore have been furnished by the .1389 parts of the mixture that disappeared by detonation; then .1389—.0454 is the quantity of water formed, or 0935

But water is composed of 7.5 of oxygen and 1 of hydrogen, therefore .0935 parts contain
hydrogen 0110
oxygen 0825

The whole quantity of oxygen therefore is (.0454+.0825) 1279

Thus the elements of the mixture are
Carbon 1286
Oxygen 1279
Hydrogen . . . .0110——.2675

The proportion of the oxygen in carbonic oxide to the carbon, is as 7.5 to 5.7, therefore the .1279 of oxygen require .0972 of carbon to form of carbonic oxide 2251

But the whole carbon is .1286, the difference therefore, or, .0314 must have been combined with the .0110 of hydrogen, to form of bihydruret of carbon 0424

.2675

And consequently the mixture was composed by volume of $\frac{75}{100}$dths of carbonic oxide, and $\frac{25}{100}$dths of bihydruret of carbon.

E. *Of Hydruret of Carbon and Hydrogen Gases.*

This analysis is very simple; convert the mixture, by detonation with an excess of oxygen in the mercurial eudiometer, into water and carbonic acid, measure the residuum, agitate it with a solution of caustic potassa, and measure it again: the quantity absorbed by the alkali denotes the carbonic acid, and the last remainder consists of the oxygen in excess; from these data the quantities of carbon and hydrogen will be readily deduced.

Suppose the volume of the mixture to be	100
Oxygen	300
Gas after detonation	225
———— the action of the potassa . .	125
The oxygen absorbed must be	175
And the carbonic acid formed	100

Now 100 volumes of carbonic acid contain 100 of the vapour of carbon and 100 of oxygen, condensed into 100 volumes; but the quantity of oxygen absorbed is 175, therefore 75 volumes have united to 150 volumes of hydrogen, to form water, and consequently the mixture was composed of 50 volumes of hydruret of carbon and 50 of hydrogen, for the former gas contains two volumes of vapour of carbon and two of hydrogen condensed into one volume. (37 A.) (*a*).

(*a*) Although uncombined carbon cannot be reduced to the state of vapour by any power we can command, yet there are considerations

F. *Of Hydruret of Carbon and Azote.*

This analysis is conducted like the preceding, except that after having absorbed the carbonic acid by potassa, the quantity of the residual oxygen and azote must be determined.

Let the volume of gas operated on be . .	100
That of the carbonic acid formed . . .	120
The oxygen absorbed	180
The azote	40

It is evident the mixture must be composed of 40 azote and 60 hydruret of carbon.

G. *Of Hydruret, or Bihydruret of Carbon and Oxide of Azote.*

Oxide of azote is soluble in about twice its volume of water at the ordinary pressure and temperature, and the hydrurets of carbon are insoluble in that fluid; by its means therefore, these two gases are easily separated. It is necessary however to deprive the water of air by boiling, before it is used; as it otherwise would be disengaged at the time the oxide of azote is absorbed, and occasion error by increasing the apparent quantity of hydruret.

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which justify the language and views adopted above, and point out the means by which the density of its vapour may be ascertained when by combination with other bodies it assumes that form; for as we know that gases unite in simple ratios of their volumes, and carbonic acid contains a volume of oxygen equal to its own bulk, it may be considered as composed of one volume of oxygen and one of vapour of carbon condensed into a single volume, and consequently the density of the latter must be equal to that of carbonic acid gas, minus the density of oxygen; or, 1.5233—1.106 = 0.4173.——Thenard, vol. I, page 161.

H. *Of the same Hydrurets and Deutoxide of Azote.*

The separation of these two gases may be accomplished by agitating them with a solution of sulphate of iron, which absorbs the deutoxide of azote, and has no action on the hydrurets of carbon; or by placing them in contact with a mixture of potassa and sulphite of potassa, which, like sulphate of iron, absorbs the deutoxide, and leaves the hydruret of carbon free.

I. *Of Hydrogen Gas and Azote.*

The analysis of this mixture is made with the detonating eudiometer in the same manner as that of a mixture of oxygen and azote; but instead of an excess of hydrogen, an excess of oxygen must be added. Two-thirds of the absorption represent the quantity of hydrogen.

K. *Of Hydrogen and Carbonic Oxide Gases.*

Like the analysis of bihydruret of carbon and carbonic oxide (28. D.)

Let the volume of the mixture be . . .	100
That of the carbonic acid formed . .	50
———— oxygen absorbed . . .	50

The mixture must consist of 50 parts of oxide of carbon and 50 of hydrogen, for the carbonic acid represents an equal volume of carbonic oxide, and carbonic oxide absorbs half its volume of oxygen; but the absorption of oxygen amounts to 50 parts; 25 therefore must have united to 50 of hydrogen.

L. *Of Hydrogen and Oxide of Azote.*

By water, as with hydruret of carbon and oxide of azote (28. G.)

M. *Of Hydrogen and Deutoxide of Azote.*

As that of deutoxide of azote and the hydrurets of carbon, by solutions of iron (28. H).

N. *Of Azote and Carbonic Oxide.*

Similar to the analysis of hydruret of carbon and azote (28. F.); remembering that the volume of carbonic oxide is equal to that of the carbonic acid formed, since 100 parts of oxide of carbon + 50 oxygen, give 100 of carbonic acid.

O. *Of Azote and Oxide of Azote.*

By water, as with oxide of azote and hydruret of carbon (28. G.)

P. *Of Azote and Deutoxide of Azote.*

Pass up 100 parts of the mixture into a graduated tube full of water, and add an excess of chlorine, the deutoxide will be soon converted into acid, and dissolved; then absorb the excess of chlorine by potassa, and the azote will be left, whose quantity, deducted from the original quantity of the mixture, gives the quantity of the deutoxide of azote.

Q. *Of Carbonic Oxide and Oxide of Azote.*

By water, like oxide of azote, and hydruret of carbon (28. G.)

R. *Of Carbonic Oxide and Deutoxide of Azote.*

By solutions of iron, like hydruret of carbon, and deutoxide of azote (28. H.)

8. *Of Oxide of Azote and Arsenuretted Hydrogen, or Bihydruret of Phosphorus.*

By water, like the mixture of hydruret of carbon and oxide of azote (28. G.)

ARTICLE THE SECOND.

§ 29. *Analysis of a mixture of two Gases belonging to the second series (§ 26.)*

A. *Of Carbonic Acid, and either of the following, Hydrochloric, Hydriodic, Fluoboric, or Fluosilicic.*

Pass up a certain quantity of the mixture into a tube over mercury, and add one twenty-fifth or one thirtieth of their bulk of water, and agitate the tube slightly: no sensible quantity of carbonic acid, but the whole of the other gas will be absorbed.

B. *Of Carbonic and Sulphurous Acid Gases.*

These may be separated in the same manner as the preceding, but as water at the common temperature and pressure dissolves only 37 times its volume of sulphurous acid gas, it is better to substitute fragments of borax, which readily absorbs that acid, and has no action on carbonic acid (Cluzel.)

C. *Of Carbonic Acid Gas and Chlorine.*

By mercury, which has no action on the first, and very readily absorbs the second at the ordinary temperatures.

D. *Of Carbonic Acid Gas and Oxide of Chlorine.*

Hydrochloric acid gas, added in excess to this mixture over mercury, reduces the oxide of chlorine to the state of chlorine, which will combine with the mercury. If the tube be agitated, the absorption is accelerated; the excess of hydrochloric acid being then dissolved by a *very small quantity* of water, the residuum will be pure carbonic acid gas, and this deducted from the original quantity of the mixture, will give the quantity of oxide of chlorine.

E. *Of Carbonic Acid and Sulphuretted Hydrogen Gases.*

Like the mixture of carbonic, and the other acid gases (29. A); using a solution of acetate of lead instead of water, which will absorb and decompose all the sulphuretted hydrogen, and leave the carbonic acid untouched.

F. *Of Carbonic Acid and Telluretted Hydrogen Gases.*

By chlorine, which decomposes telluretted hydrogen. The excess of chlorine will be absorbed by the mercury, over which the experiment must be made.

G. *Of Carbonic and Chlorocarbonic Acid Gases.*

By alcohol, which dissolves the latter, and has no action on the former.

H. *Of Sulphuretted Hydrogen, and either of the following Gases, Hydrochloric, Hydriodic, Fluoboric, or Fluosilicic.*

By water, like that of carbonic acid gas, &c. (29. A.); but since water, holding a portion of either of these gases in solution, dissolves a sensible quantity of sulphuretted hydrogen, it is better to use borax, and proceed as directed for the analysis of a mixture of carbonic and sulphurous acid gases (29. B.)

I. *Of Telluretted Hydrogen Gas, and either of the four last Gases of the preceding article.*

Like the analysis of the mixture of sulphuretted hydrogen with the same gases.

K. *Of Sulphurous and Hydrochloric Acid Gases.*

Dissolve the gases in water, and pour in an aqueous solution of pure barya. Sulphite of barya will be precipitated, which must be washed and dried without contact of air to prevent the absorption of oxygen (*a*), and hydrochlorate of barya will remain in solution. The washings of the sulphite being mixed with the dissolved hydrochlorate, add a little pure nitric acid to saturate the barya that was in excess, and afterwards nitrate of silver, to decompose the hydrochlorate of barya, and form chloride of silver, 100 parts of which, when well washed and dried, are equivalent to 25.23 parts of hydrochloric acid. The sulphite of barya, in the same manner, will denote the quantity of the sulphurous acid gas; 100 parts of the sulphite contain 29.2 parts of sulphurous acid. Suppose the chloride of silver weighs 76.89 grs. and the sulphite of barya 115.58 grs. the former denotes 19.4 grs. of hydrochloric acid gas, the latter 33.75 grs. of sul-

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(*a*) This may be accomplished by placing the precipitate under the receiver of a good air pump, over a large surface of sulphuric acid, and keeping as perfect a vacuum as possible, 'till the whole of the water shall have evaporated.

phurous acid gas. The specific gravity of hydrochloric acid gas is 1.2725; that of sulphurous acid gas, 2.2131; therefore 100 cubic inches of the former weigh 38.8 grs. and 100 of the latter 67.5. Consequently the mixture contained 50 cubic inches of hydrochloric acid gas, and 50 of sulphurous acid gas.

L. *Of Sulphurous and Fluoboric Acid Gases.*

Pass them into a tube over mercury, and introduce $\frac{1}{100}$dth of their bulk of water, which will dissolve all the fluoboric acid, and not act perceptibly on the sulphurous, especially if the experiment be made at a temperature of about 90°.

M. *Of Sulphurous and Fluosilicic Acid Gases.*

Add successively to a solution of these gases in water, solutions of chlorine, pure potassa, nitric acid, and nitrate of barya. The chlorine will change the sulphurous acid into sulphuric; the potassa precipitate the acid fluate of silica, which remains in the liquor; the nitric acid will saturate the excess of potassa; and the nitrate of barya, form with the sulphuric acid, an insoluble sulphate. The liquid must be filtered, and the filter washed, both after the addition of the potassa and of the nitrate of barya. The weight of the sulphate of barya, after being calcined, gives that of the sulphuric acid, from which the weight of the sulphurous acid and its volume may be calculated: 100 grains of sulphate of barya, indicate 27.2 grs. of sulphurous acid, or 40.3 cubic inches (29. K.)

N. *Of Hydrochloric Acid Gas and Chlorine.*

By mercury, which absorbs the latter, and has no action on the former.

O. *Of Hydrochloric Acid and Telluretted Hydrogen Gases.*

By water, which dissolves but very little telluretted hydrogen, and 464 times its volume of hydrochloric acid gas, at the ordinary temperature and pressure.

P. *Of Hydrochloric and Fluosilicic Acid Gases.*

Dissolve the gases in water, and pour an excess of barya water into the solution; an insoluble fluate and a soluble hydrochlorate will be formed, which may be separated by the filter, and (the washings being added to the hydrochloric solution) by first pouring in nitric acid to saturate the excess of barya, and then nitrate of silver, chloride of silver will be obtained, whose weight gives that of the hydrochloric acid. A mixture of fluoboric, and hydrochloric acid gases may be similarly analysed.

Q. *Of Chlorine, and one of the following Gases, Oxide of Chlorine, Fluosilicic, Fluoboric, Chlorocarbonic, Carbonic, Sulphurous.*

By mercury, which absorbs chlorine, and has no action on the others.

ARTICLE THE THIRD.

30. *Analysis of a mixture of three Gases, one of them absorbable by a solution of caustic Potassa.*

Pass up a small portion of the alkaline solution to the mixture, in a tube over mercury. When all the acid gas is absorbed, measure the residuum, and separate the two gases which compose it, by the processes already detailed (28.) Should the mixture contain two gases, absorbable by the alkaline solution, and only one not capable of combining with it, the same method may be adopted to insulate the latter, after which, the quantity of the other two gases must be ascertained by processes varying according to the nature of the gas.

ARTICLE THE FOURTH.

§ 31. *Analysis of a mixture of five Gases not absorbable by Potassa; viz. Oxygen, Azote, Hydrogen, Hydruret, or Bihydruret of Carbon, and Carbonic Oxide.*

The pressure and temperature being noted down, pass 100 parts of the mixture into a graduated tube over mercury; introduce a little water and a cylinder of phosphorus, and suffer it to remain till the phosphorus is no longer luminous in the dark; (*a*) next, measure the residuum, the difference between which and the original 100 parts, gives the quantity of oxygen; making the necessary corrections, if the temperature or pressure have varied, during the experiment; (note § 8.) The specific gravity of the remaining gases must then be ascertained, which are to be examined by the mercurial eudiometer, like the mixture of bihydruret of carbon, and carbonic oxide, (28. D.) noting the quantity of azote as mentioned, (28. F.)

(*a*) The oxygen must not exceed one third part of the mixture, that the phosphorus may be capable of absorbing it. (See note, § 28. B.)

ARTICLE THE FIFTH.

§ 32. *Analysis of a mixture of four Gases, absorbable by solution of Potassa; viz. Chlorine, Carbonic, Hydrochloric, and Fluoboric Acids.*

Absorb the chlorine by mercury, agitating the apparatus; next pass up 100 parts of the residuum into a fresh tube, (*a*) and introduce a small portion of water, which will dissolve the hydrochloric and fluoboric acids, and leave the carbonic acid free. The quantities of hydrochloric and fluoboric acids are afterwards to be ascertained, as already explained, (29. P.)

ARTICLE THE SIXTH.

§ 33. *Analysis of a mixture of four other Gases absorbable by solution of Potassa; viz. Sulphuretted Hydrogen, Carbonic, Hydrochloric, and Fluoboric Acids.*

Introduce 200 parts of the gas, with small pieces of borax, into a tube over mercury, to absorb the hydrochloric and fluoboric acids: the carbonic acid and sulphuretted hydrogen will be left, and may be separated by the process described (29. E.)

Having determined their proportions, place four or five hundred parts of fresh gas in contact with fifteen or twenty parts of water. The hydrochloric and fluoboric acids will be dissolved, and may be separated as already directed (29. P.)

(*a*) Without this precaution, a portion of deuto-chloride of mercury might be dissolved by the water at the moment of its action, which would prevent an accurate estimate of the quantity of acid.

ARTICLE THE SEVENTH.

34. *Analysis of a mixture of Gases, some of which are soluble in solution of Potassa; viz. Azote, Oxide and Deutoxide of Azote, and Carbonic Acid (a).*

Absorb the carbonic acid in 100 parts of the mixture over mercury, by a little solution of potassa; next determine the quantity of deutoxide of azote, by introducing successively to a fresh quantity of the gas, a small portion of water, a slight excess of chlorine, and some minute fragments of hydrate of potassa. The deutoxide will thus be converted into acid, and dissolved, and at the same time the carbonic acid and the excess of chlorine will be absorbed. Then, deducting the volume of carbonic acid, which is known already by the first experiment, that of the deutoxide of azote is obtained; after which the oxide of azote and the azote may be separated by water deprived of its air, in the common method (28. O.)

ARTICLE THE EIGHTH.

§ 35. *Analysis of a mixture of the preceding Gases and Sulphuretted Hydrogen.*

This analysis is very similar to the foregoing. First put a certain quantity of the gas in contact with

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(a) A mixture of this kind is obtained by the action of nitric acid on vegetable and animal matter, except that it is said to contain a little hydrocyanic vapour. If that be so, the gas must first be acted on by deutoxide of mercury, which will absorb the vapour, and form a cyanide of mercury, easily distinguished.

a small portion of super-acetate of lead, to absorb the sulphuretted hydrogen; the residuum being measured, agitate it with a little potassa, to take up the carbonic acid. For the rest the operations already detailed must be performed, taking care to deduct from the absorption which the chlorine, &c. will occasion, not only the volume of carbonic acid, but also that of the sulphuretted hydrogen.

ARTICLE THE NINTH.

§ 36. *Analysis of a mixture of Azote, Deutoxide of Azote, Hydrogen, Bihydruret of Carbon, Carbonic Acid, Carbonic Oxide, Sulphuretted Hydrogen, and Hydrochloric Acid.*

Absorb the hydrochloric acid by fragments of borax, over mercury; then pass the residuum into a graduated tube, and treat it in succession (as stated in the preceding analysis), with solutions of super-acetate of lead and potassa, the first of which will give the quantity of sulphuretted hydrogen, and the second that of the carbonic acid. The quantity of deutoxide of azote is to be determined, by agitating the gaseous mixture (previously freed from the hydrochloric and carbonic acids, and the sulphuretted hydrogen) with solution of green sulphate of iron. To ascertain the proportion of azote, hydrogen, bihydruret of carbon, and carbonic oxide, a sufficient quantity of these gases must be obtained, by placing the original mixture in contact successively with water, sulphate of iron, and potassa; after which they must be separated as already detailed (§ 31.)

DIVISION THIRD.

Analysis of Compound Gases.

§ 37. This branch of analysis was very imperfect, till M. Gay Lussac, observing that gases combine in some simple ratio of their volumes, pointed out the method by which the errors of experiment may be corrected by calculation, and accurate results obtained. We reckon at present 23 compound gases, namely,

Hydruret and bihydruret of carbon, hydruret and bihydruret of phosphorus, arsenuretted, sulphuretted, telluretted, potassuretted, and selenuretted hydrogen, cyanogen, oxide of carbon, hydruretted oxide of carbon, oxide and deutoxide of azote, oxide of chlorine, carbonic, chlorocarbonic, sulphurous, hydrochloric, hydriodic, fluosilicic, and fluoboric acid gases, and ammonia.

A. *Hydrurets of Carbon.* There are two distinct gases, composed of carbon dissolved in hydrogen, whose characteristic properties have been noticed already (§ 11. G. H.) The same method of analysis is applicable to each.

Detonate in the mercurial eudiometer, one volume of hydruretted carbon, with five volumes of oxygen, the result will be carbonic acid and water; measure the residuum, and agitate it with a solution of caustic potassa, which will absorb the carbonic acid, and leave the oxygen that was in excess.

Suppose the gas under examination to be hydruret of carbon, or olefiant gas, and that two volumes of carbonic acid, and two of oxygen remain after detonation; then three volumes of oxygen have been absorbed. Now carbonic acid contains a volume of oxygen equal to its own; consequently two volumes of that gas have combined with carbon and one with hydrogen. Again, two volumes of carbonic acid contain two volumes of the vapour of carbon, and one volume of oxygen denotes two of hydrogen; hence it follows that one volume of hydruret of carbon, is composed of two volumes of vapour of carbon and two of hydrogen, condensed into one volume, which agrees with the specific gravity of olefiant gas, for 0.1474 (twice the specific gravity of hydrogen) + 0.8346 (twice that of the vapour of carbon) = 0.9816. As bihydruret of carbon only requires two volumes of oxygen for its complete combustion, a less quantity of that gas is sufficient for its analysis.

B. There are also two compounds of hydrogen and phosphorus, which possess distinct properties, one consisting of one atom of phosphorus, and one of hydrogen, the other of one of phosphorus and two of hydrogen. Davy has named them phosphuretted hydrogen and hydrophosphoric gas, and Thomson proposes to call them hydroguret and bihydroguret of phosphorus, as I have already mentioned, (§ 9 note *a*.)

From the spontaneous inflammation which ensues, when hydruret of phosphorus comes in contact with atmospheric air, or oxygen gas, its analysis by detonation with the latter is not so easily performed, as that of the hydrurets of carbon; it may however be mixed with oxygen in a narrow tube, without undergoing spontaneous combustion, and it is found in such experiments to require for its complete decomposition, either one, or one and a half volume of oxygen. In the first case Dr. Thomson supposes that hydrophosphorous acid and water is formed, in the second phosphorous acid and water. The most satisfactory method of analysing this gas is to pass a current of electric sparks through it for a considerable time: phosphorus is deposited and pure hydrogen remains, but the volume of the gas is not altered. Hence it follows that hydruret of phosphorus consists of hydrogen gas, holding phosphorus in solution; and the quantity is discovered by substracting the specific gravity of hydrogen gas from that of the hydruret.

Specific gravity of hydruret of phosphorus	0.8114
. . . . hydrogen	0.0737
Phosphorus	0.7377

So that hydruret of phosphorus contains $\frac{1}{11}$th its weight of hydrogen. Now if we reckon the weight of an atom of hydrogen 1, and that of an atom of phosphorus 10, it is obvious that hydruret of phosphorus is composed of one atom of hydrogen and one atom of phosphorus. (Thomson's Chemistry, vol. I, page 272, fifth edition.)

C. Davy analysed bihydruret of phosphorus (hydrophosphoric gas) by heating potassium in it. The potassium combined with the phosphorus, pure hydrogen remained, and the volume of the gas was doubled. Bihydruret of phosphorus does not burn spontaneously when mixed with oxygen, but an explosion takes place when the mixture is heated to 300°, and one volume of the gas requires two volumes of oxygen for its complete combustion. As bihydruret of phosphorus contains two volumes of hydrogen (as proved by the action of potassium) it is obvious that one volume of the oxygen goes to the formation of water; the remaining volume must have united with the phosphorus. Now this is just the quantity which the phosphorus in a volume of hydruret of phosphorus requires. Hence we may conclude that the bihydruret is a compound of two volumes of hydrogen gas, united with the same quantity of phosphorus that exists in a volume of the hydruret, and condensed into one volume.

Its composition therefore must be

Phosphorus	0.7377 . .	10
Hydrogen	0.1474 . .	2

Thus we see that it is a compound of 1 atom of phosphorus and 2 atoms of hydrogen.

It is obvious also, that its specific gravity must be equal to the specific gravity of hydruret of phosphorus, added to that of hydrogen gas, or $0.8114 + 0.0737 = 0.8851$.

Sir Humphry Davy found it 0.87. *Ib.*

D. *Arsenuretted Hydrogen* Gas has not hitherto been satisfactorily analysed. Gay Lussac and Thenard decomposed it, by heating it with tin; 100 parts become 140. According to Tromsdorff, the specific gravity of arsenuretted hydrogen is 0.529. Supposing the above result to be correct, it follows that this gas is composed of 100 parts of arsenic, and 24 of hydrogen.

E. *Sulphuretted Hydrogen.* (See § 153.)

F. *Telluretted Hydrogen* Gas.—This gas has never been analysed in a direct manner. It might probably be effected by electrization, or by heating it with potassium in a bent tube over mercury; the potassium would seize on the tellurium, and leave the hydrogen free; or perhaps tin or sulphur may answer the same purpose; in the latter case sulphuret of tellurium, and sulphuretted hydrogen gas, would be formed: the latter contains a volume of hydrogen, equal to its own. In either case, the analysis must be conducted in the same way as when potassium is employed, but the heat must be greater, and continued longer. Berzelius has endeavoured to shew, by indirect experiments, that telluretted hydrogen is composed of 100 parts of tellurium, and 3.1 parts hydrogen.

G. *Potassuretted Hydrogen.* No analysis of this compound has been published, nor am I aware that its specific gravity is known. If that were ascertained, the proportions of its elements might probably be found by electrization, as in the analysis of hydruret of phosphorus.

H. *Cyanogen.*—Detonate 100 measures of the gas, over mercury, with more than 200 measures of oxygen, absorb the carbonic acid that will be formed by caustic potassa, and note its quantity; next remove the excess of oxygen by a solution of green sulphate of iron, impregnated with nitrous gas, and wash the residuum with a simple solution of green sulphate of iron, in order to get rid of any nitrous gas that may have been disengaged from the test; the azote will thus be left uncombined, and will be found, if the experiment has been carefully performed, to be equal to the original quantity of the cyanogen, whilst the carbonic acid will be equal to twice its bulk. Now as one volume of oxygen combines with one volume of carbon, and produces one volume of carbonic acid, it is evident that cyanogen must be composed of two volumes of carbon, and one volume of azote, condensed into the space of one volume. This agrees also, within a few thousandths, with the specific gravities of cyanogen and its elements.

Sp. gr. of cyanogen	1.8064
——— vapour of carbon .	0.4173
——— azote	0.9687

and $0.4173 \times 2 = 0.8346 + 0.9687 = 1.8033$.

I. *Oxide of Carbon.*—Detonate 100 parts of oxide of carbon, with 100 parts of oxygen, in the mercurial eudiometer, by the electric spark; after the explosion, the mixture will be reduced to 150 parts; next, absorb the carbonic acid, by solution of caustic potassa; it will be found to amount to 100 parts, and the remaining 50 will be the oxygen that was in excess. Now 100 parts of carbonic acid, contain 100 parts of oxygen, but 100 parts of carbonic oxide have taken 50 parts of oxygen to form 100 parts of carbonic acid, they must therefore have contained 50 parts of oxygen, before the detonation. The specific gravity of carbonic oxide is 0 9737, that of the vapour of carbon 0.4173 and that of oxygen 1.106; and $0.4173+(\frac{1.106}{2})$ .553 $=$ 0.9703. Carbonic oxide therefore consists of a volume of vapour of carbon and half a volume of oxygen, condensed into one volume.

K. *Hydruretted Oxide of Carbon.*—Dr. Thomson has very lately announced the discovery of a new triple gaseous combination of hydrogen, oxygen and carbon, to which he has given the name of hydroguretted oxide of carbon. I have taken the liberty to shorten it a syllable. It is obtained by acting on a mixture of finely powdered triple prussiate of potassa, (ferruginous hydrocyanate of potassa) and strong sulphuric acid, by heat. 50 grains of the salt and 1 drachm measure of sulphuric acid, of the specific gravity 1.884 gave 36 cubic inches of the gas. Dr. Thomson gives the following account of its properties. It has a peculiar, but not disagreeable smell, a rather aromatic taste, and leaves a lasting sensation of heat in the mouth; it is not altered by standing over water, exposed to the light. Its specific gravity is 0.993. It burns with a blue flame, and detonates with oxygen by the electric spark; three volumes of the gas require for complete combustion two volumes of oxygen, the residuum consists entirely of carbonic acid gas, and in volume exactly equals that of the inflammable gas before detonation. Now we have seen in the last article, that three volumes of carbonic acid contain three volumes of oxygen, and three of carbonic oxide one volume and a half: but three volumes of the new gas, have taken two volumes of oxygen; and three of carbonic acid are formed. It must therefore be composed of three volumes of carbonic oxide, and one volume of hydrogen, condensed into three volumes; for the specific gravity of the gas, according to Thomson, is 0.993, that of carbonic oxide 0.9737, that of hydrogen, 0.0737; and $(0.9737 \times 3)\ \frac{2.9211 + 0.0737}{3} = 0.9982$ and consequently three half volumes of oxygen, have united with the carbonic oxide and the remaining half volume with the volume of hydrogen. (See Annals of Philosophy, August, 1818.)

L. *Oxide of Azote* was analysed by Sir Humphry Davy, by detonation with hydrogen. When one volume of this gas is mixed with one volume of hydrogen, and an electric spark passed through the mixture, inflammation takes place, water is formed, and one volume of elastic matter remains, which is azote. Now as one volume of hydrogen takes half a volume of oxygen for its conversion into water, it is evident that oxide of azote must be composed of two in volume of azote, and one in volume of oxygen, condensed into a space equal to two. (Elements of Chemical Philosophy, p. 106.)

The decomposition of oxide of azote may also be accomplished by potassium or sodium, or by heating fragments of sulphuret of barya in a volume of the gas, in a small retort over mercury, by a spirit lamp; the oxygen will be absorbed, and a volume of the azote left, equal to that of the gas employed. Deducting, therefore, the specific gravity of azote, from that of its oxide, the difference will give the quantity of oxygen; thus 1.5217—0.9687 =, 553; consequently oxide of azote is formed of one volume of azote and half a volume of oxygen condensed into one volume, or by weight, azote 100, + oxygen 57.08. (Gay Lussac.)

M. *Deutoxide of Azote.*—Its analysis may be performed like that of the oxide, by sulphuret of barya: the volume of the residual azote will be found to be just half that of the deutoxide. Now 0.553 (half the specific gravity of oxygen) + 0.4843 (half the specific gravity of azote) = 1.037 the specific gravity of deutoxide of azote; consequently this gas is composed of equal volumes of azote and oxygen gases, and they combine without suffering any condensation. By weight its composition is azote 100 + oxygen 113.97. (Gay Lussac.)

N. *Oxide of Chlorine.*—The analysis of this gas is very simple. Pass 50 measures up a little tube over mercury, and apply a very gentle heat, the gas will be decomposed, with explosion, and its volume increased to 60 measures, 40 of which are chlorine, and 20 oxygen; the former may be absorbed by water, or by the mercury. It is evident from these results, that oxide of chlorine is composed of two volumes chlorine and one of oxygen, which at the moment of their combination experience a condensation equal to one-sixth of their bulk.

O. *Carbonic Acid Gas.* (See § 130)

P. *Chlorocarbonic Actd Gas.* (See § 131)

Q. *Sulphurous Acid Gas.* (See § 139)

R. *Hydrochloric Acid Gas.* (See § 155)

S. *Hydriodic Acid Gas.* (See § 154)

T. *Fluosilicic Acid Gas.* (See § 156)

U. *Fluoboric Acid Gas.* (See § 157)

V. *Ammonia.*—If equal parts by bulk of oxygen gas and ammonia be detonated by the electric spark, the alkaline gas is decomposed, water is formed, and azote disengaged.

If ammonical gas be passed over red hot charcoal, its elements enter into new combinations; azote is set free, and hydruretted carbon, and a substance resembling prussic acid are formed. If potassium be fused in a portion of ammonia in a small retort, the two bodies soon act on each other, an olive green, very fusible compound of potassium, azote and ammonia is formed, and a volume of hydrogen, exactly equal to that which the same quantity of potassium would afford by its action on water, is disengaged. If sodium be employed instead of potassium, analogous results are obtained. If ammonia be passed over either of the following metals, strongly heated in a porcelain tube, the results are extremely curious. Heat alone has not the power to decompose ammonia, but when its action is assisted by the presence of iron, copper, silver, platina, or gold, the gas is converted into hydrogen and azote, and with a facility proportionate to the degree of heat employed. Iron possesses the greatest action on the gas, next copper, and so on in the order stated. Neither of these metals, when pure, experience any diminution or increase of weight from the decomposition of the ammonia, but the physical properties of some of them are singularly altered; the iron becomes brittle, and the copper so extremely tender, that it can scarcely be touched without breaking; yet it is still extensible under the hammer; its red colour also changes to yellow, and sometimes it becomes whitish (*a*). It is very difficult to account for these results, (Thenard, vol. II, p. 141,) but these and the other experiments mentioned, sufficiently demonstrate the nature of ammonia, and that its elements are hydrogen and azote. To ascertain the proportions in which they are united, the best method of analysis is by electricity. After a current of electric sparks has been passed through a given quantity of perfectly dry ammonia, for a considerable time, it is completely decomposed, and its volume exactly doubled. The new gaseous products may then be examined by detonation with oxygen, in the manner already pointed out in the analysis of other inflammable gases, and it will be found to consist of one volume and a half of hydrogen gas, and half a volume of azote, which when combined in the form of ammonia, are condensed into one volume.

Hence ammonia is composed by weight, of
Hydrogen $(.0737 + 1.5)$ . . 0.11055
Azote .. $(\frac{6687}{2})$ 0.48435
.59490

(*a*) According to M. Gay Lussac, a similar effect is produced, when hydrocyanic vapour is passed over iron, heated red in a porcelain tube. (An. de Ch. vol. 95. p. 153.)

CHAPTER THE THIRD.

Of the Analysis of Combustible Bodies.

DIVISION THE FIRST.

To distinguish the simple unmetallic Combustibles.

§ 38. The number of the undecompounded combustibles not metallic, properly so called, is six; viz. Hydrogen, boron, carbon, phosphorus, sulphur, and selenium. M. Thenard has also included iodine and azote in the same class. If the power of combining with oxygen be alone considered sufficient to constitute a combustible, whether heat and light be developed or not, they are properly placed in that rank, but the arrangement adopted by Dr Thomson with regard to iodine, I think preferable, who places it with oxygen, chlorine, and fluorine, as a "*supporter* of combustion." The characters of azote, have induced the same author in the last edition of his Chemistry, to class that body by itself. Sir Humphry Davy, with more propriety, places it amongst the undecompounded inflammable or *acidiferous* substances, not metallic. I have suffered iodine to retain the place assigned it by M. Thenard, as otherwise it must have formed a division by itself; since, from the classification adopted in this Essay, it cannot be put with chlorine and oxygen, as they are gases, and the existence of fluorine is as yet only hypothetical, however strong the analogies which render it probable. Azote

I omit in this place altogether; its properties have been described in the second chapter.

A. *Hydrogen*, (see § 9. C. and § 11. E.)

B. *Boron* is solid, insipid, inodorous, of a greenish brown colour, pulverulent, infusible, fixed; without action on oxygen gas, at common temperatures, but burns very brilliantly when heated in it, and boracic acid is formed; nitric acid, with the assistance of a gentle heat also converts it into boracic acid.

C. *Carbon*, like boron, is solid, insipid, inodorous, pulverulent, infusible, fixed, and generally black: when heated to redness in an excess of oxygen gas, it burns with great brilliancy, and is wholly converted into a permanently elastic fluid, carbonic acid.

D. *Phosphorus* is ductile, almost as sectile as wax; more or less transparent; fusible at about 104°, and luminous in the dark; it diffuses white vapours in the air, at ordinary temperatures; absorbs oxygen, and produces phosphorous acid, and lastly, inflames violently by the contact of a burning body.

E. *Sulphur* is a solid, insipid, yellow, volatile substance, fusible at 342° Faht.; it burns with a blue flame, and is wholly converted into sulphurous acid gas, possessing the suffocating odour of burning sulphur.

F. *Selenium*.—On visiting some sulphuric acid works at Gripsholm, in which the Pyrites of Fahlun is employed, Berzelius observed, that the bottom of the large leaden chamber was covered with a reddish coloured mass that had subsided from the liquid acid. It consisted chiefly of sulphur, and inflamed and burnt like that substance, but left a bulky ash, which gave before the blow-pipe a strong odour, similar to that of radishes, or putrid cabbage, which induced Berzelius to suppose it contained tellurium: but on a more minute investigation he found it proceeded from a new substance, which he named Selenium. It has the following properties: on becoming solid after fusion, when cooled rapidly, its surface has a metallic brilliancy, and deep brown colour resembling polished hematite. Its fracture is lead coloured, conchoidal, glassy, and perfectly metallic. When fused and cooled very slowly, its surface is lead-coloured, uneven, and without polish; and its fracture granulated and dull, very like that of metallic cobalt. Selenium does not readily crystallize, but when it separates spontaneously from a solution of hydroselenuret of ammonia, it appears to affect the form of cubes. When selenium is precipitated by zinc from a diluted solution, its colour is cinnabar red; and if the liquid and precipitate be boiled together, it contracts, and becomes almost black. Sulphurous acid mixed with a very dilute solution of selenic acid, and exposed to the light, reduces the selenium, and the surface of the fluid becomes covered with a brilliant gold-coloured pellicle, which, if taken off by a piece of paper or glass, and dried, resembles a pale gilding, and is permanent.

Selenium gives a deep red powder; in very thin laminæ, it is translucent, and ruby red. It softens by heat, and fuses at a few degrees above 212°. It preserves a soft state as it cools, when it may be kneaded between the fingers like wax, or drawn out into threads, which have considerable elasticity, and viewed by transmitted light are red; by reflected, grey, with a perfect metallic brilliancy.

Heated in a retort, selenium boils below a visible red heat, and sublimes in the form of a deep yellow gas, not of so intense a colour as the vapour of sulphur, but more so than that of chlorine: it condenses in black drops like mercury. Heated in the air, it gives red fumes without any particular odour, and if not in contact with a burning body, it sublimes without alteration, but if it touch flame it tinges its edges a pure azure blue, and exhales a strong smell of putrid cabbage; owing to the formation of oxide of selenium. Selenium is not a conductor of heat or electricity, neither could Berzelius render it electric by friction. Selenium is easily scratched by the knife; it is as brittle as glass, and very friable; its specific gravity is between 4.3 and 4.32.

Berzelius considers selenium as a metal; but its transparency and glassy fracture, the low heat at which it fuses, the soft state it retains whilst cooling enabling it to be drawn out into threads, and above all its not being a conductor of heat and electricity, deny it a place amongst those bodies, notwithstanding its metallic brilliancy in certain states and high specific gravity. Indeed Berzelius himself seems to be of that opinion, although he decides to the contrary, for he says, "according to its chemical properties this body ranks between sulphur and tellurium; but it has more properties in common with sulphur than with tellurium." Surely its physical properties lead to the same conclusion. (Ann. de Ch. vol. IX. p. 171, new series.)

G. The characters of *iodine* are very decided; at common temperatures it is solid and has a metallic appearance; its colour is bluish, its odour analogous to that of chlorine; gradually heated in a matrass it melts, is transformed into a violet coloured vapour, and condenses on the upper part of the vessel in brilliant plates; placed in contact with solution of potassa, it disappears and forms iodate and hydriodate of potassa, the latter of which remains in solution, and the former is precipitated; from the hydriodate, the iodine may be precipitated by solution of chlorine. The most delicate test for iodine is *starch*; if added to any liquid containing it, with a few drops of sulphuric acid, the iodine is indicated by a blue colour of greater or less intensity. (Henry's Chemistry, vol. II. p. 40.)

DIVISION THE SECOND.

On the distinguishing Characters of the Metals, (a.)

§ 39. First, if when placed in contact with water at common temperatures, the metal suddenly decompose it, with effervescence, it belongs to the second

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(*a*) M. Thenard divides the metals into six sections, according to their affinities for oxygen.

Section I. Contains silicium, zirconium, aluminium, yttrium, glucinium, magnesium, and thorinium. These seven have never been reduced, and are classed with the metals by analogy only.

Section II. Comprehends those metals which absorb oxygen gas at the highest, and instantly decompose water, at all temperatures, uniting with its oxygen, and disengaging the hydrogen with effervescence; they are six, viz. potassium, sodium, lithium, baryum, calcium, strontium.

Section III. To this section belong those metals which absorb oxygen gas at the highest temperatures, but require a red heat to decompose water; it comprehends four metals, manganese, zinc, iron, tin.

Section IV. The metals of this section also absorb oxygen gas at the highest temperatures, but are incapable of decomposing water at any; they are fourteen in number, viz. arsenic, molybdena, chromium, tungsten, columbium, antimony, uranium, cerium, cobalt, titanium, bismuth, copper, tellurium, and cadmium. This section is subdivided into two parts, the first consists of the first six metals, which are acidifiable; the second of the remaining eight, which are only oxidable.

section, and to determine its individual nature, the liquid must be saturated with hydrochloric acid, concentrated, and examined by the proper re-agents.

A. *Potassium.*—Solutions of subcarbonate of potasssa, soda, or ammonia, have no effect on hydrochlorate of potassa; but it is rendered turbid by a solution of platina, and of sulphate of alumina.

B. *Sodium.*—Hydrochlorate of soda is not rendered turbid by solutions of the alkaline subcarbonates, nor by a solution of platina, or sulphate of alumina.

C. *Lithium.*—Hydrochlorate of lithia is not affected by either of the tests mentioned in the last article. When evaporated to dryness, the residual mass is soluble in alcohol, and imparts a crimson colour to its flame, similar to that given by strontia, but more beautiful; it is very deliquescent, and fusible much below a red heat; is easily decomposed by carbonate of silver, and the carbonate of lithia requires at least 100 parts of water for its solution; it does not easily afford regular crystals by evaporation, fuses at an incipient red heat, and if the experiment be made on silver or platina, becomes sensibly caustic to the tongue. Nitrate of lithia is deliquescent, the sulphate is not, but crystallizes in four sided prisms with rhomboidal bases, and requires rather a higher heat for its fusion than the hydrochlorate.

Section V. Contains those metals which absorb oxygen gas only at certain temperatures, are incapable of decomposing water, and whose oxides are reduced wholly, or in part at a red heat; they are four, nickel, lead, mercury, and osmium.

Section VI. The last section contains those metals which neither absorb oxygen gas nor decompose water at any temperature, and whose oxides are reduced at a heat below redness; they are six, viz. silver, palladium, rhodium, platina, gold, and iridium.

D. *Baryum.*—Hydrochlorate of barya is rendered turbid by solutions of the alkaline subcarbonates, and when diluted with a *very large* quantity of water, sulphuric acid forms a white precipitate in it, insoluble in excess of acid. When concentrated by evaporation it affords crystals in the form of square plates, on which alcohol has no action.

E. *Strontium.*—A solution of the hydrochlorate of strontia, is, like the preceding, rendered turbid by the alkaline subcarbonates; diluted with a great quantity of water, sulphuric acid occasions no precipitate with it, and when concentrated, it deposits on cooling, needle formed crystals, not deliquescent, but soluble in alcohol, to which they communicate the property of burning with a beautiful crimson flame.

F. *Calcium.*—A solution of hydrochlorate of lime, is also rendered turbid by the subcarbonates of potassa, soda, ammonia, and lithia; when largely diluted with water, sulphuric acid occasions no precipitate with it, but oxalate of ammonia an immediate one; it is difficultly crystallizable, and the residuum left by evaporation is deliquescent and soluble in alcohol.

§ 40. If the metal have no sensible action on water at common temperatures, but dissolves in weak sulphuric acid, disengaging hydrogen gas, it must be either manganese, zinc, or iron.

A. *Iron*—A solution of potassa, soda, or ammonia, throws down from solutions of protoxide of iron, a white or greenish white oxide, which, by contact with the air, passes quickly to a deep green, and then to a reddish yellow; prussiate of potassa (*a*) gives a preci-

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(*a*) I retain the old name *prussiate*, in preference to the more scientific one of *ferruginous*, or *ferrohydrocyanate* of potassa, not only on the pitate at first white, but becoming deep blue, by exposure to the air, or the addition of a few drops of a solution of chlorine; and with infusion of galls, the solution becomes first deep purple and then black. If the iron be in the state of peroxide, the alkalies throw down at once a reddish precipitate, and prussiate of potassa a deep blue.

B. *Zinc*—The caustic alkalies produce with solutions of zinc, a white precipitate, not altered by exposure to air, and soluble in excess of alkali. Solutions of prussiate and hydrosulphuret of potassa also give a white precipitate.

C. *Manganese*—Solutions of potassa and soda give a white precipitate with solutions of manganese, insoluble in excess of alkali, and becoming chesnut brown by contact with the atmosphere. Alkaline prussiates and hydrosulphurets also give white or nearly white precipitates; and lastly, the oxide which the alkaline solutions separate, being dried and mixed with five or six times its weight of subcarbonate or nitrate of potassa, and exposed for a quarter of an

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score of brevity and euphony, (many of the new names, by the way, are marvellously cacophonous) but also to avoid the mistakes that might arise, from omitting the first part of this long title; since the action of the simple hydrocyanates, and that of the ferrohydrocyanates, on metallic solutions, is very different, as may be seen by reference to the table of colours of the precipitates, by these reagents, in the 3d vol. of my Author's Treatise, p. 530, and at the end of the article "hydrocyanic acid," in this Essay.

Dr. Thomson considers the salt in question as a compound of potassa and *ferrocyanic* acid, which he thinks (but does not tell us why he thinks so) consists of iron in the metallic state, and cyanogen, and consequently that hydrogen is not one of its elements. He adopts the name of *ferrocyanate* of potassa.—Thomson's Chemistry, vol. 2. p. 295. 5th edition.

hour to a red heat affords a green mass, possessing all the properties of mineral chamelion (a).

§ 41. If the metal have no action on water, or dilute sulphuric acid at ordinary temperatures, but is acted on by nitric acid, at least when assisted by heat, it must be one of the following; viz. tin, antimony, molybdena, arsenic, cobalt, uranium, copper, nickel, palladium, mercury, bismuth, tellurium, silver, lead, or cadmium. Cobalt, uranium, copper, nickel, and palladium, being the only metals of the above fifteen, which give coloured solutions with nitric acid, can but be confounded with each other, and they will readily be distinguished individually by the properties of their respective solutions.

A. *Cobalt.*—The solution is violet red, and gives a violet blue precipitate with alkalies; a green with alkaline prussiates, and a black with alkaline hydrosulphurets. Lastly, the oxide, separated from the solution by an alkali, has the property of colouring a large quantity of borax, producing a fine blue glass, when fused with that substance at a red heat.

B. *Palladium.*—The solution is red; proto-sulphate of iron reduces the metal; hydrochlorate of tin forms with it a black, and prussiate of potassa, an olive coloured precipitate: lastly, by evaporation to dryness, and a red heat, both the nitrate and the oxide are decomposed.

C. *Copper.*—The solution is blue, or greenish blue, and forms with potassa and soda, a blue precipitate,

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(a) Mineral chamelion forms a solution with water, which is at first green; but after standing a few minutes becomes violet red, and deposits reddish yellow flakes. The effect is accelerated by a drop or two of nitric acid.

insoluble in excess of alkali, and which becomes brown by heat; with ammonia a bluish white precipitate, soluble in excess of ammonia, and giving a fine azure blue solution; with prussiate of potassa, a red brown precipitate; and, lastly, a plate of iron immersed in the solution, is immediately covered with a coat of copper.

D. *Nickel*—The solution is grass green; potassa and soda throw down from it a light green oxide; ammonia changes its colour to a violet blue; prussiate of potassa gives an apple green precipitate, and hydrosulphuret of potassa a black one. A plate of iron does not reduce the metal.

E. *Uranium*—Its solution is yellow, or inclining to yellow, and by evaporation, and cooling, lemon coloured crystals separate from it; prussiate of potassa throws down a blood-red precipitate; alkaline hydrosulphurets a brown, and potassa, soda, and ammonia, a pale yellow precipitate, soluble in the carbonates of potassa and soda. An iron plate does not reduce the oxide.

F. *Mercury* is easily known by its fluidity at common temperatures, and the property of boiling and being volatilized in the metallic state below a red heat.

G. *Arsenic*, when heated red without access of air, volatilizes, and condenses in the upper part of the vessel in crystals. Thrown on burning coals, it absorbs oxygen, and passes to the state of deutoxide, which flies off in white vapours, diffusing a strong smell of garlic; heated with weak nitric acid, it dissolves, the solution on cooling deposits white crystals, and gives a yellow precipitate with sulphuretted hydrogen; lastly, when saturated with potassa, so as to form both a nitrate and an arseniate, it gives a green precipitate with deuto-sulphate of copper.—(C. Appendix).

G*. *Tin*, *Antimony*, and *Molybdena*, are distinguished from all the other metals by the action of concentrated nitric acid, which does not dissolve, but converts them into a white or yellowish white powder, insoluble in the same acid.

H. *Molybdena* is infusible, (*a*) the powder into which it is converted by nitric acid, is sensibly soluble in water. The solution reddens litmus, and becomes blue, if a plate of zinc or tin be immersed in it; it readily unites with and saturates potassa, soda and ammonia, forming soluble and crystallizable salts with the two first, and with the latter a salt which leaves a syrupy mass by evaporation. They are all decomposed by the strong acids.

I. *Antimony* dissolves in strong aqua regia, (*b*) the solution gives a white precipitate with water, and an orange yellow one with sulphuretted hydrogen. If antimony be combined with sulphur, and treated with

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(*a*) The great powers of Brooke's blowpipe (in which a stream of condensed oxygen and hydrogen gases in the proper proportions to form water, is employed) and of voltaic electricity, to fuse the most refractory substances, have, strictly speaking, almost annihilated the character of infusibility; however, as in many cases it is one of great importance, it would be inconvenient to reject it, but it must henceforth be employed with reference to the heat of the furnace and the common blowpipe. I found molybdena fuse very readily by a current of electricity from a voltaic battery of twenty pairs of plates, each plate of sixteen feet surface, and it immediasely yields to the power of Brooke's instrument. (Phil. Trans. 1815.)

(*b*) Thenard calls this, more correctly, hydro-chloro-nitric acid. I retain the shorter, old name. I need hardly add, that it is a mixture of nitric and hydrochloric acids.

a solution of sub-carbonate of soda, it produces the substance formerly called *Kermes*, a part of which separates from the liquor on cooling (*a*).

K. *Tin* is ductile, dissolves by heat in hydrochloric acid, with disengagement of hydrogen gas, and forms two hydrochlorates, not decomposable by water: the one gives a brown precipitate with sulphuretted hydrogen, and partially deoxydates several substances, as the acids of arsenic and the hydrochlorate of gold, with the latter of which, it produces the purple precipitate of cassius; the other hydrochlorate of tin gives a pale yellow precipitate, with sulphuretted hydrogen, and has no effect on solutions of gold.

K*. Bismuth, tellurium, silver, lead, and cadmium, like mercury and arsenic, give colourless solutions with nitric acid.

L. *Bismuth* is brittle, very fusible, and its solution in nitric acid is precipitated white by water, and black by sulphuretted hydrogen.

M. *Tellurium* is brittle, very fusible and volatile; heated by the blowpipe it burns with a blue flame, forming an oxide, which sublimes in white vapours, exhaling a *smell similar to that of radishes*; (*b*) its

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(*a*) Kermes is a hydrosulphuret of antimony, of a beautiful orange colour, which, by exposure to the air, gradually absorbs oxygen and becomes white, giving off sulphuretted hydrogen.

(*b*) According to some late experiments of Berzelius, pure tellurium gives no smell, either when heated before the blowpipe, or when its oxide is reduced; and the only mode by which the odour of radishes can be produced from it, is to heat the metal in a glass tube, closing the end by the finger, so that its vapour may force a passage through the softened glass. It then burns as it escapes through the hole with a blue flame, and exhales the odour in question. (An. de Ch. T. 9. p. 164.)

solution in nitric acid is precipitated white by water, and orange brown by sulphuretted hydrogen. The precipitate formed in it by potassa and soda; is redissolved by an excess of alkali.

N. *Silver* is ductile, and not oxidable by the air; its solution in nitric acid, forms a precipitate with the hydrochlorates, insóluble in excess of nitric acid, but very soluble in ammonia; the oxide, separated from it by potassa or soda, is reduced by a low red heat.

O. *Lead* is ductile, and very fusible. Its solution in nitric acid has a sweet taste, is precipitated white by sulphuric acid, and sulphates, and black by sulphuretted hydrogen, and when evaporated and calcined, a yellow oxide is obtained, which by fusion is converted into litharge.

P. *Cadmium* is a new metal, lately discovered by M. Stromeyer. It possesses the following properties:

In hardness, ductility, and external appearance, this metal has great resemblance to tin, and is said to give the crackling noise when bent, hitherto supposed to be peculiar to that metal. Its specific gravity at 60° is 8.67, when hammered 9.05. It fuses considerably below a red heat, and is very volatile.

It dissolves with great facility in cold diluted nitric acid, and the solution, evaporated to dryness, yields a deliquescent salt, soluble in alcohol, to the flame of which it does not impart any colour. Neither sulphuric nor hydrochloric acids act readily on cadmium in the metallic state, but they instantly dissolve its oxide. The hydrochlorate evaporated to dryness attracts moisture, and is wholly volatilized at a heat below redness.

A neutral solution of nitrate of cadmium gave with

Prussiate of potassa	a white precipitate.
Hydrosulphuret of ammonia	a fine bright yellow.
Solution of sulphuretted hydrogen	ditto. When heated it passes to a crimson, but becomes yellow again on cooling.
With the alkalies and their carbonates	a white precipitate.
Chromate of potassa, Tincture of galls, Sulphate of soda, Succinate, and Benzoate of ammonia.	no precipitate.

Zinc readily precipitates cadmium in the metallic state, from its solution in hydrochloric, or sulphuric acid, but not so readily from its solution in nitric acid.

The white oxide thrown down by ammonia from its solution in an acid, is redissolved by an excess of ammonia; pure potassa does not dissolve the oxide, but precipitates it from the ammoniacal solution. (See Journal of Science, January, 1819.)

Cadmium does not tarnish by exposure to the air, at common temperatures, but by heat, is converted into a fixed oxide, of an orange yellow colour, easily reducible to the metallic state. The oxide of cadmium gives no colour to borax, and its solutions in the acids are also colourless. (Annales de Chimie, vol. 8. p. 100. new series)

§ 42. If the metal have no sensible action on concentrated and boiling nitric acid, but be attacked by aqua regia, it must be either osmium, tungsten, cerium, gold, or platina.

A. *Osmium*, when oxidated by being heated in contact with the air, evaporates and exhales a strong odour, analogous to that of chlorine; when calcined with an equal weight of nitrate of potassa, in a small retort, it yields a white sublimate which has a similar odour, is very caustic, very fusible, burns vividly with ignited charcoal like nitre, and forms a colourless solution in water, which becomes blue by infusion of galls, and has the same odour as the sublimate. Zinc, alcohol, and ether, separate blackish flakes. Lastly, by distillation, even after being mixed with an acid, a liquor passes into the receiver, which possesses the same properties.

B. *Tungsten* yields, by calcination with an equal weight of nitrate of potassa, a mass in great measure soluble in water; the solution is colourless; hydrochloric acid occasions a white precipitate, which, by an excess of boiling acid, becomes yellow, and possesses the properties of tungstic acid. This acid is yellow, inodorous, insipid, solid, much heavier than water; does not redden paper stained with litmus; neither fuses, nor is decomposed in the furnace, nor experiences any change when heated in the air, or in oxygen gas. It is difficultly reducible by heat with carbonaceous matter, and combines with bases and forms neutral salts.

C. *Cerium* dissolves with heat in aqua regia; the solution when deprived by boiling of its excess of acid is colourless, and sweet; it gives white precipitates with prussiate, and hydrosulphuret of potassa; is not made turbid by sulphuretted hydrogen nor infusion of galls; potassa, soda, and ammonia, separate from it a white oxide, insoluble in excess of alkali, which by calcination, absorbs oxygen from the air, and becomes brown red; tartrate of potassa forms a white precipitate, which by calcination assumes the same colour as the oxide, and by the action of boiling hydrochloric acid, affords chlorine, and a colourless deliquescent hydrochlorate; with nitric acid it gives a salt of a yellowish colour.

D. *Gold* dissolves in aqua regia, the solution is yellow; it is precipitated purple, or violet, or blackish brown by hydrochlorate of protoxide of tin; and is not affected by the hydrochlorate of the deutoxide of that metal: it is immediately reduced by sulphate of iron and the yellowish brown precipitate assumes by calcination the appearance of unpolished gold; lastly, ammonia separates from it a yellowish powder, which when dry, detonates by heat.

E. *Platina* gives with aqua regia a yellow solution inclining to orange, which is not precipitated by sulphate of iron; when concentrated, salts with base of potassa or ammonia, throw down from it, a yellow precipitate soluble in water; that with hydrochlorate of ammonia is reduced by a red heat to the metallic state.

§ 43. If the metal be not acted on either by boiling nitric acid, or aqua regia, it must be, either chromium, titanium, columbium, rhodium, or iridium.

A. *Chromium*, when triturated, and mixed with an equal weight of nitrate of potassa, and heated to redness for half an hour, affords a yellowish mass, soluble in water, to which it imparts the same colour; the excess of alkali being saturated with nitric acid, the solution precipitates nitrate of silver purple, acetate of lead bright yellow, and acid nitrate of mercury red. The last precipitate, exposed to a strong heat, gives a green oxide, fusible with borax, to which it imparts an emerald green colour.

B. *Titanium* is of a copper red colour; by calcination in contact with air, it becomes blue: when heated to redness with an equal weight of nitre, and the mass lixiviated with a large quantity of water, the residuum forms a pale yellow solution with hydrochloric acid, which when freed from excess of acid by concentration, gives a blood-red precipitate with infusion of galls, a red with prussiate of potassa, a deep grass green with hydrosulphuret of potassa, and a white with alkalies; it is not made turbid by sulphuretted hydrogen. If a bar of tin be immersed in it, it assumes a red tinge, and a blue one with a plate of zinc; lastly, by evaporation, it becomes gelatinous and nearly insoluble in water.

C. *Columbium (a)* by calcination with nitrate of potassa, yields a mass which treated with weak nitric acid, and well washed, leaves a residuum of columbic acid, possessing the following characters:

It is white, pulverulent, insipid, inodorous, faintly reddens litmus, is infusible and indecomposable by heat, and sparingly soluble in water. When an excess of columbic acid is boiled with a solution of potassa, it forms a salt having a sharp disagreeable taste,

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(*a*) It is with peculiar pleasure I retain this name, originally assigned it by Mr. Hatchett, who first made the metal known to us, and very properly adopted by Mons. Thenard. That the term should ever have been changed to that of "*tantalum*," in England especially, seems very extraordinary, for, without detracting from the merit of Mons. Ekeberg, the subsequent discoverer of the same substance in the Swedish mineral called tantalite, that of priority is evidently the right of our enlightened countryman; and the minute portion on which he was obliged to operate, enhances the praise due to his experiments. See Philosophical Transactions, 1802.

which crystallizes in brilliant plates like boracic acid, requires a large quantity of water for its solution, and is thrown down again by all the strong acids. Boiling hydrochloric and sulphuric acids dissolve it, and the solutions give an olive coloured precipitate with prussiate of potassa, a reddish brown with hydrosulphuret of ammonia, a bright orange with infusion of galls, and a white with alkaline carbonates. The sulphate also becomes milky with water, and by the action of concentrated phosphoric acid, is converted into a white opake jelly, but the hydrochloric solution is affected by the phosphoric acid only.

D. *Rhodium* is a brittle, white metal, extremely difficult of fusion. Vauquelin could not fuse it on charcoal, though the combustion was urged by a current of oxygen gas. Dr. Wollaston, who discovered this substance, fused it, but not so perfectly as to be free from cavities. Its fracture is granular, and its hardness about that of iron; it is insoluble in all the acids, and has no action on the air or on oxygen gas. When strongly calcined with potassa or nitre, and the mass treated with water, the residuum gives a red solution with hydrochloric acid, capable of forming rose coloured triple salts with the alkalies, insoluble in alcohol, and readily obtained in crystals.

E. *Iridium* dissolves with difficulty even in concentrated aqua regia, but calcined with potassa, or nitre, it oxidates and gives a black pulverulent mass, which imparts a blue colour to water; the insoluble residuum forms a blue solution with hydrochloric acid, becoming by the action of heat successively green, violet, purple, and yellowish red, colours that are immediately destroyed by sulphate of iron, and sulphuretted hydrogen, and restored by chlorine. A very small portion of the hydrochlorate of iridium occasions a brick red precipitate, when hydrochlorate of ammonia is added to a solution of platina. If liquid ammonia be poured gradually into a solution of hydrochlorate of iridium, sufficiently concentrated, it deposits a great quantity of small brilliant crystals of so deep a purple as to appear almost black; a few grains of these crystals give an orange red colour to a large quantity of water, which sulphate of iron, sulphuretted hydrogen, and metallic iron, zinc, or tin immediately destroys.

SECTION THE THIRD.

Analysis of Metallic Alloys, (a).

§ 44. First place the alloy in contact with water, at the common temperature; if it contain potassium, sodium, lithium, barium, strontium, or calcium, hydrogen gas will be disengaged, and the liquor become alkaline; next, add an excess of subcarbonate of ammonia, to convert the different oxides, arising from the decomposition of the water into carbonates; filter the liquor to separate the insoluble carbonates of barya, strontia, and lime, and evaporate the filtered liquid to dryness, by which the sub-carbonates of potassa, soda, and lithia, will be obtained. Re-dissolve them in water, neutralize them by sulphuric acid, and submit the sulphates to crystallization. The sulphate of potassa, being the least soluble, will crystallize first, and may thus be separated from the other

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(a) The metals are supposed to be merely mixed, and to have no other action on re-agents than they possess separately, which is not strictly correct.

two; it affects the form of octohedrons. The remaining sulphates of soda and lithia, are too equally soluble to be separated in the same manner; therefore convert them both into hydrochlorates, by adding hydrochlorate of barya till it cease to occasion any further precipitate; filter, evaporate the solution to dryness, and digest the residual mass in strong alcohol. The hydrochlorate of lithia will be wholly dissolved, and the common salt remain untouched. If the liquid when considerably reduced by evaporation occasion no cloud with concentrated solution of platina, there is no necessity for crystallizing the salt, since it can only in that case, contain the sulphates of soda and lithia. The insoluble carbonates must be collected from the filter, and dissolved in hydrochloric acid, the solution evaporated to dryness, and the residuum heated with successive portions of boiling alcohol, which has no action on hydrochlorate of barya, but readily dissolves the hydrochlorates of strontia and lime. Next dilute the alcoholic solution with water, pour in sub-carbonate of potassa, which immediately throws down the strontia and lime in the form of carbonates, to separate which the precipitate must be re-dissolved in nitric acid, and the solution again evaporated to dryness. Boiling alcohol will then take up the nitrate of lime and leave the nitrate of strontia undissolved.

§ 45. If water have no action on the alloy, boil it with weak sulphuric acid; the manganese, iron, and zinc, (and even the nickel, according to M. Tupputi,) which it may contain, will be dissolved, and hydrogen gas evolved, as in the preceding case. If the alloy contain,

A. *Iron*, its solution gives a precipitate with prussiate of potassa, at first white, but which, by exposure to the air or the action of chlorine, becomes dark blue.

B. *Nickel*, ammonia gives a clear violet blue solution with it, when the oxides insoluble in that alkali are separated by the filter.

C. *Zinc*, the iron of the solution being peroxidated, by boiling it with nitric acid, pour in subcarbonate of potassa, and digest the precipitate in caustic fixed alkali; filter and mix the alkaline solution by degrees, with a small excess of nitric acid: white flakes will fall down, and almost immediately be re-dissolved, and a nitrate formed, which will produce with the alkalies, the hydrosulphurets, and alkaline prussiates, all the phenomena mentioned in speaking of zinc. (40 B.)

D. *Manganese.*—To ascertain if this metal be contained in the alloy, let the precipitate which remained undissolved by the caustic fixed alkalies, in the examination for zinc, be treated with ammonia, well washed, and dissolved in nitric acid; next evaporate the solution to dryness, and heat it to about 400°. If manganese be present, water will then form a solution, which, being evaporated, will yield a fresh residuum capable of affording the mineral chamelion by fusion with potassa.

§ 46. After the action of water and diluted sulphuric acid, strong, boiling hydrochloric acid is next to be employed. If hydrogen gas be evolved by the action of the acid, and the solution gives with gold a brown or purple, and with sub-carbonate of potassa a white precipitate, the latter insoluble in strong nitric acid, the alloy contains tin.

§ 47. After the successive action of water, weak sulphuric and hydrochloric acids, treat the mixture with boiling nitric acid, which will dissolve or at least oxidate the arsenic, molybdena, antimony, cobalt, uranium, bismuth, tellurium, copper, nickel, lead, mercury, silver, palladium, and cadmium; but have no sensible action on chromium, tungsten, columbium, titanium, cerium, osmium, rhodium, platina, gold, or iridium. Dilute the solution with water, if that fluid do not make it turbid, and filter and wash the residuum; but if water disturb its transparency the solution must be diluted with weak nitric acid, which will produce no change in it. The residuum being separated by the filter, and well washed with the same diluted acid, must be then treated with hydrochloric acid, to dissolve those metals which the nitric had only oxidated, namely, the portion of antimony, and tin, that may have escaped the first action of the hydrochloric acid, the arseniate of bismuth, if arsenic and bismuth were present, and perhaps also, some molybdate: the two solutions are then to be examined.

§ 48. *First solution.*

A. The excess of nitric acid must be driven off by evaporation, at a moderate heat; if the solution become turbid during the operation, it probably contains an arseniate or molybdate, and perhaps both, To ascertain this, separate the precipitate, wash it with water or weak nitric acid, and treat it with hydrosulphuret of potassa, which will convert it into a soluble arseniate, or molybdate of potassa, and an insoluble sulphuret of the metal with which either acid was combined. Then saturate the liquid with an acid, filter, and try it, as well as the sulphuret which may have been formed, by the proper tests.

B. If molybdic acid be present, sulphuric acid will throw it down from the concentrated liquid as a white powder.

C. If the solution contain arsenic acid, evaporate it to dryness, mix the residuum with dry soap, and calcine it in a small earthen retort, arsenic will sublime and crystallize in the neck of the retort. As to the sulphuret, aqua regia will dissolve the metal it contains, which must be one of those just mentioned, and therefore easily recognised.

The first concentrated solution must now be examined for bismuth, palladium, silver, lead, copper, tellurium, mercury, cobalt, uranium, and cadmium. If it contain,

D. *Bismuth*, water precipitates a white oxide, which when washed, is blackened by sulphuretted hydrogen, fuses at a red heat into a yellowish mass, and is reduced on charcoal before the blow-pipe, affording a very fusible and brittle metal.

E. *Lead*, after the solution is diluted with water, it affords with sulphuric acid, or sulphates, a white precipitate, which sulphuretted hydrogen immediately blackens, like the preceding: the precipitate also being boiled with solution of nitrate of barya, affords a liquid, from which white crystals, having a sweet taste, like those obtained by treating litharge with nitric acid, separate by evaporation.

F. *Silver.*—If after the action of water and sulphuric acid, hydrochloric acid occasions a white, flocculent precipitate, insoluble in an excess of acid, but very soluble in ammonia, the alloy contains silver.

G. *Palladium.*—Green sulphate of iron separates this substance from its solution in the metallic state. It is a white brilliant metal, and forms a red solution with nitric acid, from which a brown powder is thrown down by hydrochlorate of protoxide of tin.

H. *Copper.*—If this metal be present, a polished plate of iron immersed in the solution, soon becomes covered with a red metallic coating of copper.

I. *Tellurium.*—After the bismuth, lead, silver, and palladium are separated, if tellurium be present, subcarbonate of potassa will give a precipitate partly soluble in caustic potassa; when this alkaline solution is neutralized by an acid, it deposits a white oxide, which being mixed with lamp black and oil, and calcined in a retort, the metal is obtained in the form of bluish white globules, sublimed in the upper parts of the vessel.

K. *Mercury.*—Heat to redness in a retort the portion of the precipitate of the preceding experiment, undissolved by the alkali: if a vapour sublime, condensible by water into brilliant metallic globules, fluid at common temperatures, mercury is contained in the alloy. Its presence may also be ascertained, by heating the alloy in a retort, prior to its solution in nitric acid.

L. *Cadmium.*—The bismuth, lead, silver, copper, palladium, tellurium, and mercury, being separated by the preceding methods, the remainder of the precipitate by subcarbonate of potassa, from which the mercury has been distilled, must be dissolved in hydrochloric acid, a considerable excess of ammonia added, and the solution filtered. Dilute the filtered liquid and pour in a solution of pure potassa, which will precipitate the cadmium in the form of a white hydrated oxide.

M. *Cobalt.*—The cobalt will remain in solution in the alkaline fluid, from whence potassa has separated the cadmium, and will be obtained by boiling it, till no further precipitate ensues. When this precipitate is fused with from 20 to 25 times its weight of borax, it gives a peculiarly fine deep blue glass.'

N. *Uranium.*—Treat the ammoniacal precipitate of the preceding experiment (L) with nitric acid, evaporate the solution to dryness, pour water on the residuum and repeat the operations several times; if uranium be present a yellow liquor will be obtained possessing the properties of nitrate of uranium (41 E.)

§ 49. *Second Solution.*—The hydrochloric solution must be concentrated in the same manner as the nitric, and when the greater part of its excess of acid, is driven off, add by degrees a small excess of hydrosulphuret of potassa. The arsenic and molybdic acids, which it may contain will unite with the alkali and remain in solution, whilst the oxides whatever they are, will be precipitated in combination with sulphuretted hydrogen or sulphur; then after having filtered the liquor, treat it as stated (48. A.B.C.) to distinguish the two metallic acids. The precipitate, which perhaps will consist of hydrosulphuret of antimony or tin, and sulphuret of bismuth, must be boiled with strong hydrochloric acid, which readily decomposes and dissolves the hydrosulphurets, and has no action on sulphuret of bismuth. If this solution be rendered turbid by water, it contains antimony, and a solution of gold will shew if it contain tin; bismuth will easily be detected by the action of nitric acid, which will dissolve the sulphuret and afford nitrate of bismuth, crystallizing in small four sided prisms, and decomposable by water, which throws down the oxide of bismuth from its solution. A deposit of sulphur and some sulphate of bismuth, is also occasioned by the action of the nitric acid.

§ 50. Having treated the alloy with water, and the acids as directed, calcine the residuum, with rather more than equal weight of nitrate of potassa, in a platina crucible. If it be composed of chromium, tungsten, columbium, titanium, cerium, osmium, rhodium, platina, gold, and iridium, the chromium, tungsten, and columbium will be acidified, and unite to the potassa; the titanium, cerium, iridium, and osmium, will be oxidated, and perhaps a portion of the platina also. The mass must now be treated, first with boiling water, then with concentrated hydrochloric acid, and lastly with aqua regia, and these processes repeated till the whole mass is dissolved. Thus three solutions will be obtained; the first or alkaline solution will contain the chromium, tungsten, and columbium, and a part of the osmium.

A. To be certain that it contains osmium, pour in nitric acid, filter, if it become turbid, and distill the clear fluid in a glass retort. If the colourless liquid which passes into the receiver, have an odour similar to that of chlorine, be turned blue by infusion of galls, and deposit black floculi, by the action of zinc, osmium is present.

B. *Chromium.*—After the examination for osmium saturate the excess of acid with an alkali; if the acid nitrate of mercury now produce a red precipitate, which becomes green by exposure to a strong heat, it indicates chromium.

C. *Tungsten.*—If this metal also be present in the solution, sulphuric, nitric, hydrochloric acids will occasion a white precipitate, which changes to yellow by being boiled with aqua regia.

D. *Columbium.*—Boil the precipitate by either of the acids, just mentioned, in hydrochloric acid; evaporate the solution to dryness, calcine the residuum and treat it with distilled water. If columbium be present, a white powder will remain, which possesses all the properties of columbic acid. The columbic acid may possibly be coloured by a small portion of oxide of iridium, precipitated with it; the latter may probably be decomposed, by boiling the alkaline solution with slips of zinc, which would reduce the iridium and separate it in the form of a black powder, without having any action on the columbic acid.

E. The hydrochloric solution will contain the titanium, cerium, iridium, and rhodium: it must be concentrated, diluted with water, filtered, and a plate of iron immersed in the solution: lastly, when the iron ceases to occasion any further precipitate the clear liquor is to be decanted, and a solution of tartrate of potassa poured into it. The water will precipitate the greatest part of the titanium in the state of oxide (§ 77 P.); the iron throws down the iridium, in the form of a black metallic powder, and the tartrate of potassa separates the cerium in the state of a white insoluble tartrate, which by calcination at a red heat, leaves an ochre coloured oxide, and this being treated with hydrochloric acid, disengages chlorine, and affords a colourless sweet solution, &c. (§ 42 C.)

The oxide of titanium will be easily known by the characters already detailed (§ 43 B). The iridium and rhodium will be discovered, by calcining them afresh in a platina crucible with an equal weight of nitrate of potassa, lixiviating the mass, and treating the residuum which will be chiefly composed of the oxides of these metals, with boiling hydrochloric acid.

To the concentrated solution add ammonia, not quite in sufficient quantity to saturate the excess of acid, which will throw down an ammoniaco-hydrochlorate of iridium, in the form of small shining black particles. The solution must then be evaporated to dryness, and water slightly acidulated with hydrochloric acid, poured on the residuum, which will scarcely take up any thing but the ammoniaco-hydrochlorate of rhodium. By separately calcining the two salts, their metals will be obtained nearly pure.

F. The solution by aqua regia, must be examined for gold and platina. However small a portion of the latter it may contain, it will be detected by concentrating the solution and adding a concentrated solution of hydrochlorate of ammonia. A yellow precipitate will fall down, which yields platina by calcination (§ 42. E.) The solution must next be tried by protosulphate of iron, and hydrochlorate of tin. If it contain gold, the latter will produce the purple precipitate of cassius, and the ferruginous salt will instantly throw down metallic gold. Should the solution contain a small portion of iridium, which is possible, the precipitate by hydrochlorate of ammonia will be orange yellow, unless very concentrated.

§ 51. *Analysis of some complicated Alloys, Tin, Bismuth, Lead, Copper, and Silver* (a).

A. Heat the alloy with an excess of nitric acid of the specific gravity of about 1.23; evaporate the

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(a) I shall henceforth confine myself to general directions, without noticing the necessary operations of washing, filtering, drying, &c. The reader must by this time be too conversant with these analytical details to need their repetition.

solution nearly to dryness, and pour water on the residuum, which will dissolve the nitrates of silver, lead, and copper, and leave the peroxide of tin and oxide of bismuth. Separate these oxides and treat them afresh with nitric acid, as is mentioned (§ 61); their weights will give the quantity of tin and bismuth in the alloy.

B. To ascertain the proportions of silver, lead, and copper, pour into the solution first, hydrochloric acid, which will form chloride of silver; then sulphate of soda will throw down sulphate of lead; and lastly, hydrate of potassa, will precipitate deutoxide of copper. (See the analyses of the alloys of tin and lead, of gold and silver, and of zinc and copper, for the estimates of the quantities of lead, silver, and copper) (*a*).

§ 52. *Tin, Bismuth, Lead, Silver, Copper, and Zinc.*

The quantities of the first four metals are to be ascertained as in the preceding analysis, and the two others, which will remain in solution, may be separated by potassa, as in the analysis of brass, (§ 59. A, B.) The alkali will redissolve the oxide of zinc, and leave the deutoxide of copper.

§ 53. *Tin, Bismuth, Lead, Silver, Copper, Zinc, and Manganese.*

The preceding methods will separate all but the copper and manganese, which will remain mixed toge-

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(*a*) When the hydrochloric acid ceases to occasion a further precipitate, boil the solution, which will redissolve any chloride of lead, that may have been precipitated with the silver. As soon as the chloride of silver has subsided, decant the clear liquor, whilst still hot, and then add e sulphate of soda.

ther in the state of oxide; ammonia will dissolve the first, and leave the second, and by evaporation to dryness, and a red heat, the ammonia will be expelled, and the deutoxide of copper obtained pure. The weight of the manganese will be known from that of the peroxide obtained.

§ 54. *Tin, Bismuth, Lead, Silver, Copper, Zinc, Manganese, Gold, and Platina* (a).

By treating this alloy also like the former, the other metals are separated, and a residuum composed of peroxide of tin, gold, and platina obtained. Hydrochloric acid will dissolve the oxide of tin, which may be thrown down again by ammonia. The gold and platina must then be dissolved by aqua regia, and proto-sulphate of iron poured into the solution to precipitate the gold in its metallic state; a current of sulphuretted hydrogen passed into the remaining solution will precipitate sulphuret of platina, which by calcination in contact with the atmosphere, will yield the platina pure.

§ 55. *Tin, Bismuth, Lead, Silver, Copper, Zinc, Manganese, Gold, Platina, and Iron.*

Separate the bismuth, lead, silver, copper, and zinc, by the processes already described. The iron in the state of peroxide will remain mixed partly with the oxide of manganese, and partly with the gold and

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(a) The nitric acid is supposed in this analysis, to have no action on the platina, which perhaps is not correct, since we know that when alloyed with gold and silver, it is soluble in that acid.

platina, and the oxide of tin. To finish the operation therefore, it only remains to analyse the two residua. Boil the last with solution of potassa, to separate the oxide of tin, and then with hydrochloric acid, which will dissolve the oxide of iron. The oxide of tin may be thrown down from the alkaline solution, by nitric acid, the oxide of iron by ammonia.

The remaining gold and platina, are to be treated as in the preceding analysis.

The oxides of iron and manganese may be separated by one of the two following processes:

The first consists in dissolving them in sulphuric acid, diluting the solution with water, and adding by degrees a weak solution of potassa. A reddish precipitate of subsulphate of iron, and a yellowish white one of oxide of manganese are thus obtained, but the latter does not fall down till a considerable time after the former.

As soon therefore as the further addition of small quantities of the alkali ceases to render the solution turbid; it must be passed through the filter, in order to collect the subsulphate of iron, which must be calcined to drive off the sulphuric acid, and the oxide added to that which has been separated from the tin. Thus all the oxide of iron will be obtained, from which the quantity of the metal may be known, (*a*). The weight of the oxide of manganese will in like manner give that of the manganese.

The second method is founded on the decomposition of nitrate of iron by evaporation, whilst nitrate of

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(*a*) It is possible a little oxide of iron may be found in the washings of the oxide of bismuth; in that case it may be thrown down by potassa, and added to that already obtained.

manganese suffers no alteration in the process. Dissolve the mixed oxides in nitric acid, evaporate the solution to perfect dryness, and slightly calcine the residuum, then treat it with water, and throw the whole on a filter, which will retain the oxide of iron, and the solution of nitrate of manganese will pass through, from which the oxide may be separated by potassa (*a*).

(*a*) Very superior to either of the foregoing, are the following methods proposed by Mr. Hatchett.

1st Process—" A solution of any ore of manganese having been made as usual in muriatic acid, and filtrated, must be diluted with three or four pints of cold distilled water. To this diluted solution, add gradually pure ammonia, occasionally stirring the liquor until the acid has become perfectly neutralized, a few drops of ammonia may then be added; so that the liquor shall very slightly restore the blue colour to litmus paper which has been reddened by acetous acid. The ferruginous precipitate must then be separated by filtration, and the liquor which passes will be found devoid of colour, and contains the pure manganese in permanent solution. It affords a white precipitate, with prussiate of potassa, and the oxide of manganese may be obtained by evaporating the solution to dryness, and by expelling the muriate of ammonia by heat; after which, if any of the muriate should be suspected to remain, it may be separated by washing the oxide upon a filter."

2nd Process.—" Pure oxide of manganese may be also obtained, by adding ammonia in considerable excess to the cold diluted muriatic solution, which then without loss of time must be poured upon a filter of one fold. The liquor which passes, becomes in a few minutes turbid and brownish, a pellicle is formed, and in about twenty-four hours the greater part of the manganese separates spontaneously in the state of brown oxide; and if the remaining liquor be evaporated to dryness and heated, the whole of the oxide will be obtained. But the objection to this method is that the manganese is so rapidly separated from the ammoniacal solution, that it is scarcely possible, even by the quickest filtration, to prevent some part from being deposited on the filter, so that it becomes again mixed with the precipitate of iron, alumine, &c." Annals of Philosophy, Vol. II. p. 344.

DIVISION THE FOURTH.

Analysis of several Alloys, especially those employed in the Arts.

§ 56. *Mercury and Tin, Mercury and Bismuth, Mercury and Silver, Mercury and Gold.*

To determine the proportion of the constituent parts of either of these amalgams, (*a*) heat it gradually

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The advantage of the use of ammonia in separating the oxides of iron and manganese, consists, according to Mr. Faraday, in the solubility of the triple, or rather double salts of ammonia and manganese. If to a solution of pure sulphate of manganese, a drop of ammonia be added, an immediate precipitate ensues; but if the solution be first acidulated with sulphuric acid, in such proportion, that for every particle of sulphate of manganese it contains, there shall be formed a particle of sulphate of ammonia, the double soluble salt is produced, on which the further addition of ammonia has no effect.

When sulphate of iron and sulphate of manganese are dissolved together, the addition of ammonia decomposes the sulphate of iron, its oxide is precipitated, and the fresh formed alkaline sulphate combines with the sulphate of manganese. If the proportion of sulphate of iron be such, that the number of its particles exceeds that of the particles of sulphate of manganese, no precipitation can ensue; but if the reverse be the case, then as soon as the whole of the former are decomposed by the ammonia, the further addition of the alkali throws down oxide of manganese; and the results are first a precipitate of oxide of iron, next of manganese, and a quantity of the double salt, proportionate to the sulphate of iron in the original mixture, remains in permanent solution. In such a case, Mr. Faraday remarks, sulphuric acid ought to be added to the solution before the ammonia. He farther observes, "The two

(*a*) This term is exclusively applied to the alloys of mercury with other metals.

in a small retort, having the extremity of its neck loosely stopped with linen rag, and immersed in water, the mercury will sublime and condense in the receiver, whilst the other metal remains in the retort.

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metals may be separated from each other, by carefully adding ammonia till the solution is neutral, without advancing to the formation of the triple salt," (Hatchett's first process) "but then the uncertainty of the exact point of neutralization occurs, and this is rendered greater, because a further addition of ammonia does not render the solution alkaline until much manganese has been precipitated. In analysis therefore, the first method (Hatchett's second process) is best, though in the preparation of pure manganese and its compounds, the second is more economical, and equally certain." (Journal of Science and the Arts, No. II, p. 154.)

The truth of these views is easily demonstrated. Mix together a solution of sulphate of ammonia, and one of sulphate of manganese, so that the former shall be rather in excess. Ammonia will produce no precipitation in the mixture. As in analysis the proportion of iron and manganese can seldom be supposed to be known before-hand, it will be better always to add some sulphuric or hydrochloric acid, according to the nature of the solution, previous to using the ammonia.

There are yet two other methods of separating iron from manganese, depending partly on the tendency of the latter metal to form triple salts with ammonia, which are not affected by the pure alkalies, and partly on its power of decomposing ammoniacal salts. They are both valuable additions to our knowledge on this subject, and due to the indefatigable and able researches of Mr. Faraday.

To a mixed solution of iron and manganese, add a solution of hydrochlorate of ammonia, and then pour in pure potassa. The iron will be precipitated immediately, but the manganese will remain in solution, as a double salt: or, having dissolved the two metals in a aqua regia, (by which means the iron will be peroxidated) throw both down by solution of caustic potassa, wash them by decantation, and digest them in hydrochlorate of ammonia, with a little sugar. The manganese will be redissolved, and the iron left. (Journal of Science and the Arts, Vol. VI, p. 357.)

All other amalgams of mercury, and any metal not volatile below a red heat, may be analysed in the same manner.

§ 57. A. *Tin* and *Lead.*—Introduce a certain quantity (100 grains for instance) of the alloy into a mattrass, add six or seven times its weight of pure nitric acid, of the specific gravity of about 1.26, and expose it to a heat gradually raised. When the metallic particles have disappeared, and the acid ceases to give off nitrous gas, it must be evaporated to dryness, water poured on the residuum, and the whole thrown on a filter and washed, 'till the washings (which must be added to the filtered solution) no longer redden litmus, nor are blackened by sulphuretted hydrogen. The peroxide of tin remaining on the filter, must then be dried and calcined, and deducting 21.4 per cent. for the oxygen, its weight gives the quantity of tin in the alloy. Reduce the filtered liquid by evaporation, and precipitate by sulphate of soda; collect the sulphate of lead, wash, dry, and weigh it; 100 of sulphate of lead contain 68.1 of lead.

B. *Plumber's Sólder.*—Plumber's solder, which contains two parts of lead, and one of tin, may be analysed like the preceding alloy; but if any copper be present, as is often the case, an additional operation is necessary. After the lead has been separated, subcarbonate of potassa or soda must be added to the solution to throw down the copper in the state of subcarbonate, which a red heat will convert into oxide, from whose weight that of the metal is deduced.

C. *Tin* and *Copper.* The analysis of this alloy must be conducted like that of tin and lead, (§ 57 A.) except that, instead of sulphate of soda, we must add to the filtered liquor an excess of solution of hydrate of potassa, wash the precipitate of deutoxide of copper thus obtained, till the washings are not affected by nitrate of barya, and dry and heat it red to convert it into pure deutoxide of copper. Its weight, deducting 20 per cent. for oxygen, gives that of the copper.

D. *Gun Metal. (Bouches à feu.)*—This is generally composed of 89 parts copper and 11 tin, which must be separated by nitric acid; but, as a little iron and even lead may always be suspected in the alloy, and would be dissolved with the copper, the solution must first be concentrated to drive off the greater part of the acid in excess, then diluted with water, and the lead thrown down by sulphate of soda. To the filtered liquor add an excess of ammonia, which will precipitate the oxide of iron in red flakes, and retain the copper in solution. The iron being separated, caustic potassa must be added in excess, and the whole evaporated to dryness to expel the ammonia; the residuum heated in distilled water and the oxide of copper collected, &c.; the weights of the several metals will then be deduced from the sulphates and oxides obtained. The alloy of gongs and cymbals is similar to the preceding, differing only in the proportions of the metals. They may be analysed in the same manner.

E. *Bell Metal.*—Tin and copper serve also as the base of this alloy, but zinc, lead, and iron are likewise often found in it, which renders its analysis more complicated. The alloy may be treated in the same manner as the *gun metal*, but after the addition of caustic potassa, and evaporation to dryness, the residuum must be boiled in distilled water in order that the excess of alkali may redissolve the oxide of zinc, which may then be separated as directed (§ 59 A.)

58 A. *Lead* and *Antimony.*—This analysis may be made precisely as that of the alloy of tin and lead, (§ 57 A.) deducting 26.5 per cent. for the oxygen of the deutoxide of antimony.

B. *Tin* and *Antimony.*—Solution of the alloy in aqua regia, and precipitation of the oxide of antimony by water is impracticable in the analysis of this alloy, in consequence of the antimony carrying a large quantity of the oxide of tin down with it.—(An. de Chimie. vol. LV. p. 276.) The following method is recommended by M. Chaudet, (An. de Chimie. vol. III. p. 376. new Series.) The proportion of antimony in the alloy must be pretty nearly ascertained by a previous experiment on five parts of the alloy and 100 of tin fused together, laminated and treated with hydrochloric acid; the undissolved portion will indicate pretty nearly the quantity of antimony. The alloy is then to be fused with such a portion of tin, that this metal may be to the former as 20 to 1, including the tin in the alloy. The addition of the tin must be made with some care that the combination of the metals may be perfect. M. Chaudet places them wrapped in paper in a small crucible, covers them with charcoal powder, and fuses them under the muffle of a cupelling furnace. The button when cold is cleaned and laminated, cut into small pieces, and fused again as before; and this operation is repeated a third time, but without laminating the button, with a piece of paper placed between the metal and the charcoal powder, that the button may be perfectly homogeneous. The new alloy is then to be rolled into a very thin plate, cut into small pieces, and boiled in a flask with an excess of pure hydrochloric acid of the specific gravity of 1.19 for two hours and a half at least. The whole of the tin will be dissolved, but the antimony remain untouched. The solution is then to be diluted with distilled water, and the insoluble matter collected on a filter; its weight will be exactly that of the antimony in the alloy.

If the alloy contain any lead it must be laminated with great care, as that metal adds extremely to its brittleness.

The quantity of lead may be ascertained by treating a portion of the alloy with nitric acid, and precipitating the lead by sulphuric acid. M. Chaudet has also analysed an alloy of tin and bismuth in the same manner, but in this case it is better to use nitric acid, which dissolves the bismuth and leaves the tin.

C. *Printer's types* are formed of four parts of lead, one of antimony, and a very small portion of copper. Separate the antimony by nitric acid, as directed, (§ 58. A.) and treat the solution in the same manner as that obtained in the analysis of plumber's solder. (§ 57. B.)

§ 59. A. *Zinc* and *Copper.*—Dissolve 100 grains of the alloy in weak nitric acid, with a gentle heat, dilute the solution with a little water, and add a considerable excess of hydrate of potassa or soda, boil for a quarter of an hour, filter and wash the residuum (adding all the washings to the filtered solution,) till the water does not turn syrup of violets green, or paper, stained with turmeric, brown. From the weight of the deutoxide of copper remaining on the filter, when dried and calcined, deduct one-fifth for oxygen; the remainder gives the proportion of copper in the alloy. To the filtered alkaline solution, containing the oxide of zinc, add first a small excess of hydrochloric or sulphuric acid, and then sub-carbonate of potassa or soda; carbonate of zinc will fall down, and being washed, dried, and heated red, will be converted into oxide; the weight of which, deducting 19.61 per cent. gives that of the zinc.

B. *Yellow Brass.* (Laiton.)—When brass consists merely of zinc and copper, the preceding analysis is all that is necessary to determine their proportions; but it sometimes contains besides a small portion of lead. In this case, after solution of the alloy in nitric acid, and the expulsion of the greater part of the excess of acid by heat, the lead must be separated by sulphate of soda, and the remaining solution treated in the manner just mentioned.

§ 60. A. *Silver* and *Gold.*—Laminate the alloy, and treat it by nitric acid as in the preceding analysis, till nitrous gas ceases to be disengaged; the residuum well washed, and heated red, gives the quantity of gold. Next pour hydrochloric acid into the solution to throw down the silver, wash the precipitate, dry and weigh it; 100 parts of chloride of silver are equivalent to 75.5 of silver. If the proportion of silver in the alloy be very small, the nitric acid will only effect its partial solution; in that case add as much silver to the alloy by fusion, as will make it at least equal to three-fourths of the mass. Account must be taken of the quantity of silver thus added, at the end of the operation, as will presently be noticed.

B. *Silver* and *Copper.* (*a*) Dissolve the alloy in nitric acid, and dilute the solution with water, throw down the silver by hydrochloric acid, and filter the

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(*a*) There is another mode of analysing this alloy, viz. by cupellation, the only method employed in commerce to determine the standard of all kinds of money, bullion, and plate.

liquor, washing the precipitate, till ammonia ceases to produce a blue colour; then mix the washings with the filtered liquor, reduce it by evaporation, and add an excess of hydrate of potassa or soda to separate the deutoxide of copper, from which the quantity of copper in the alloy is ascertained, (§ 59 A.) as that of the silver is learnt from the chloride, (§ 60 A.)

C. *Silver*, *Copper*, and *Gold*.—This alloy also must be treated with nitric acid, which will dissolve the silver and copper and leave the gold untouched, whose proportion is to be ascertained as in (§ 60 A.) and that of the silver and copper as mentioned.(§ 60 B.) In this analysis, as in the two preceding, if the alloy contain too little silver or copper in proportion to the gold for the nitric acid to act readily on it, it must be combined with an additional quantity of one of them, and by preference with silver, because that metal not being readily oxidated, it is easy to keep account of the exact quantity added. (*a*)

§ 61. *Bismuth*, *Tin*, and *Lead*.—First heat the alloy in excess of nitric acid of the specific gravity of about 1.26, till the nitrous acid gas ceases to be evolved. The liquid must then be evaporated nearly to dryness, and the remaining mass washed with successive portions of water; by these means all the nitrate of lead will be dissolved, and a white residuum obtained, consisting of the oxides of tin and bismuth. This being treated afresh with nitric acid, the whole of the oxide of bismuth will be re-dissolved; but, in order to separate the portion of nitrate of bismuth,

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(*a*) We may also determine the quantity of copper in this alloy by cupellation, but it is only by nitric acid that the gold and silver can be accurately separated.

which may adhere to the oxide of tin without decomposing it, the latter must be washed with weak nitric acid; this done, the analysis is almost finished. It is only necessary to dry, calcine, and weigh the oxide of tin to obtain the quantity of that metal; (§ 57 A.) for that of the bismuth evaporate the solution of its nitrate to dryness, decompose this by heat in a platina crucible, and weigh the oxide; 100 parts contain 89.87 bismuth. Lastly, precipitate the lead by sulphate of soda, &c. (§ 57 A.)

DIVISION THE FIFTH.

Analysis of Alloys by Cupellation.

§ 62. Cupels, which are small porous cups, formed by ramming well washed, and pulverised bone ashes into a mould, may be considered as filters, permeable only to certain fluids, or as sponges, which absorb some bodies, but have no action on others. Fused metallic oxides readily penetrate these vessels, but to the metals themselves they are quite impermeable. Hence they afford a ready method of separating those metals which are not capable of change by the combined action of heat and air, from others that are oxidated by their influence. When such mixtures are kept in fusion on them with access of air, the oxides which form, are gradually absorbed by the cupel, and the inoxidable metal is at last left in a hemispherical form on the surface, like a globule of quicksilver on a plate of glass, pure and unalloyed. If the oxides be not fusible by themselves, at the requisite degree of heat, a portion of some other metal must be added, which may promote their fusion.

Lead is generally preferred for this purpose: in all cases it is necessary that the inoxidizable metal be not volatile, and that it be sufficiently fusible to form a round button; otherwise it would remain disseminated, adhering to the portion of oxide with which the surface of the cupel is impregnated, and could not be completely collected. The operation is performed by placing the two metals on a cupel, which has previously been thoroughly dried at a red heat, and exposing it for a certain time, in the muffle of a cupelling furnace, to a temperature from about 26° to 35° of Wedgewood's pyrometer.

Since only gold and silver are inalterable, fusible, and fixed at this temperature, they alone can be correctly separated from other metals by cupellation (*a*).

§ 63. A. *Lead* and *Silver*.—Place the cupel under a muffle, and when heated to about 27° of Wedgewood's pyrometer, put the alloy on it (*b*). It soon fuses and is covered with a coat of oxide of lead, becomes flattened, gives off fumes, and considerable motion ensues on its surface, which by continual

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(*a*) Platina, and probably other metals of the last section, may be separated by cupellation, but they must first be combined with a sufficient quantity of silver and gold, to make them fusible.

(*b*) The muffle at this degree of heat appears *bright red*; the cupel is usually placed at about one-third of the depth of the muffle from its mouth.

I have retained M. Thenard's mode of expressing very high temperatures, by degrees of Wedgewood's pyrometer, for want of a better, though I am well aware how indefinite the ideas it conveys must necessarily be. It is much to be lamented that we have not some means of accurately measuring intense heats. The philosopher who should invent such an instrument would confer an essential obligation on the science of chemistry in general, and especially on the subject of our immediate attention, as well as on many of the arts and manufactures. As it stands at present, the eye of experience is the only pyrometer the operator can rely on.

renewing it, assists the oxidation. The lead thus gradually passes to the state of oxide, and the oxide as it forms, fuses, and is absorbed by the cupel, *except a very small portion*, that volatilizes, and occasions the fumes just mentioned. Together with these phenomena others present themselves, not less important to the progress of the assay.

The alloy diminishes in volume, and leaves a trace or circular mark on the basin of the cupel, differing in colour according to the nature of the metals oxidated. Thus copper gives a darkish brown tinge, iron a reddish one, and tin, a white; and I may here observe, that when the latter metal abounds in an alloy, it is necessary to use a greater portion of lead than common for its complete removal.

The alloy which at first was evidently flattened becomes more and more convex, and presents continually increasing shining points. At this period, the lead is almost entirely absorbed, and the cupel must be brought forward towards the mouth of the muffle. There, in a very short time, the shining points disappear. The alloy exhibits all the colours of the rainbow, loses for a moment its lustre, and suddenly becomes brilliant by an instantaneous movement, technically termed *brightening* or *fulguration*. By this last phenomenon we know that the operation is completed. The door of the muffle which has hitherto been removed to a small distance from the mouth, is now to be applied to it, and the silver suffered to become quite solid, before the cupel is withdrawn: (*a*) when

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(*a*) Instead of a common door, the mouth of the muffle is generally closed with sticks of charcoal, which are more easily applied or withdrawn so as to increase or diminish the draft of air to the surface of cold, the button of silver is taken off with pincers, the lower part brushed, to remove any particles of the cupel that might have adhered to it, and weighed. Its weight deducted from that of the alloy gives the weight of the lead. It is very essential not to withdraw the cupel from the muffle immediately after the brightening, because the silver by cooling too rapidly would retain too much lead, and also be liable to *spring*, or shoot out in filaments like fine wire; for at the moment the exterior of the assay solidifies, it experiences such a contraction as to force out a portion of the still liquid metal within, so as to form a sort of arborization on the surface of the button, and it is not only spirted on the cupel, but even entirely out of it. Moreover the assay cannot be considered good, if the button adhere strongly to the cupel, and be not well rounded, brilliant, and crystallized on the upper surface, whilst the lower presents an unpolished granular white appearance. If the surface be dull and flattened the heat has been too great and a portion of the silver volatilized; on the contrary, if it be brilliant in many points, and present here and there an unpolished white crystalline appearance, have little cavities below, adhere obstinately to the cupel, and yellowish scales remain on the vessel, the heat has been insufficient, and the silver still retains a portion of lead; in either case the assay must be repeated.

B. *Copper* and *Silver*.—The oxide of copper fuses with difficulty; a portion of lead must therefore be added in this analysis.

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the assay; and the inner ends of the charcoal becoming ignited, prevent an undue chilling of the cupel, which would be prejudicial to the success of the operation.

Suppose the alloy to be examined is that of the French coin, which contains 9 parts of silver and 1 of copper. Put 105 grains of lead on the cupel, placed as before, and heated to the same degree (63 A.) and when it is melted and its *surface bright*, add with the tongs 15 grains of the alloy. The three metals almost instantly unite and form a melted mass which presents the same phenomena as the alloy of silver and lead (63 A.) After the brightening has taken place, it only remains as in the former instance to weigh the button of silver, to know the proportion it bears to the copper. The quantity of lead to be added must depend on that of the base metal in the alloy; for instance, to assay silver plate, whose standard is 0.95, only three parts of lead to one of the assay, are necessary; for a silver alloy of the standard of 0.8, ten parts are required, and for the assay of base coin, whose standard is 0.2, sixteen or seventeen (*a*.) In what has just been said, the standard of the assay is supposed to be known, when otherwise it must be determined pretty nearly, by a previous trial with about two grains of the alloy and an equal quantity of lead.

(a) For this last assay, only half the quantity can be operated on unless the cupel be very large.

The following table, by M. d'Arcet, will be found useful, the standard of the assay being known.

Standard.	Quantity of copper.	Proportion of lead to one of the assay.	Proportion of lead to that of the copper.
Fine silver 1000	0	0, 3	0
950	50	3	60 : 1
900	100	7	70 : 1
800	200	10	50 : 1
700	300	12	40 : 1
600	400	14	35 : 1
500	500	16 to 17	32 : 1
400	600	ditto	26.666 : 1
300	700	ditto	25.857 : 1
200	800	ditto	20 : 1
100	900	ditto	17.777 : 1
Fine copper	1000	ditto	16 : 1

The proportions stated in this table, are founded on the results of M. d'Arcet's experiments, which may be seen at length in the Annales de Chimie, tom. I, page 66 (new series). It appears that the quantity of lead to be added to the assay, by no means increases in the same ratio as that of the base metal in the alloy, and consequently, contrary to what might have been expected, it cannot be deduced by calculation from any given data. The table, presuming it to be correct, acquires additional value from this consideration.

§ 64. Determination of the quantity of *gold*, in ingots, coins, vases, and utensils.

If these articles were composed merely of gold and copper (*a*) they would only require to be cupelled with

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(*a*) Amongst these articles, those only that are made of fine gold, that is, gold from which the silver has been separated by acids, are quite free from the latter metal.

lead, like the alloy of copper and silver (63 B); but since a small quantity of silver is always to be suspected in them, they must be combined with a certain proportion of that metal prior to the cupellation, and the assay afterwards treated with nitric acid; the first of which operations is called *quartation* (because usually performed with three parts of silver to one of gold) and the last the *depart.*

By these means both the silver added, and that which formed part of the alloy are dissolved, whereas otherwise, the silver of the alloy being enveloped by the gold, the greater part would escape the action of the acid. In either case the gold remains untouched.

Let us take as an example the gold coin of France, which in 1000 parts should contain from 898, to 902 of gold, the mean of which is 900. When the cupel is heated to 28° or 29° Wedgewood, place 120 grains of pure lead on it, and when this is fused and its surface bright, add 8 grains of gold and 22 grains of fine silver. All the phenomena already described occur in this instance, and the same appearances announce the completion of the process (63 A.) It must therefore be conducted like that for the cupellation of silver, except that, as the assay is not liable to spring, the cooling may be more rapid (*a*). The cupellation being finished, and the assay cleaned with the scratch brush, flatten it with a hammer on the anvil, and anneal it, that it may not crack in passing through the rollers by which it must be laminated, so as to form a plate about $\frac{1}{60}$th of an inch thick; then anneal it again and roll it up in the form of a cylinder; after which place it in a small pear-shaped matrass of the capacity of 6 cubic

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(*a*) Fine gold alone sometimes springs.

inches, with about 2¼ oz. of pure nitric acid of the specific gravity of 1.1462, and apply heat very gradually till the acid boils; after boiling 22 minutes, decant the acid, and replace it by an ounce of pure nitric acid of the specific gravity of 1.283, and boil it ten minutes; then decant again and wash the assay with repeated portions of distilled water. After this fill the matrass with water, invert it, and immerse its neck in a small earthenware crucible, into which the cylinder or "*cornet*," will thus fall without being broken; then, dexterously raising the neck of the matrass, pour off the water from the crucible, and place it on hot ashes, to evaporate the greater part of the remaining water. This done, heat the gold to redness under the muffle, let it cool, and weigh it.

This method answers perfectly with gold *alloys*, but if the gold be *fine*, the result is always rather too great by one or two thousandth parts; that is, the standard, instead of being 1000, becomes apparently 1001 or 1002. M. Chaudet recommends the addition of three parts of silver to one of fine gold, and to cupel the mixture with half its weight of lead; after cupellation the button is to be rolled out into a plate about three inches long, coiled up and heated three or four minutes in nitric acid of the specific gravity of 1.1462, or as long as nitric vapour is disengaged; the acid is then to be decanted, and fresh added, of the specific gravity of 1.283, in which it is to be boiled ten minutes, and again decanted, and a fresh quantity of the same acid poured on, and the boiling repeated for ten minutes more; the coil is then to be washed with distilled water, heated, and weighed. The weight of the coil will now be found exactly equal to that of the gold employed. (An. de Chimie. tom. 4, p. 356, new series.)

Gold assays are generally made on half the quantity employed in the assay of silver, but the portion of lead and silver to be added must depend on the standard of the gold. The quantity of silver should be nearly three times that of the supposed quantity of gold in the alloy; if greater, the cornet would not have sufficient solidity, and would break; if less, some silver might remain united with the gold. As to the proportion of lead it must increase with the quantity of copper; thus, in assays of fine or nearly fine gold, that is to say, of 1000, .997, .995, .990, only sufficient lead must be employed to promote the ready fusion and combination of the gold and silver; eight parts to one of gold are generally enough, whereas 14 must be employed with gold of .900, and 20 with that of .750.

The approximate standard of the piece is known by cupelling one part of gold with about 20 parts of lead, and considering the button obtained as pure gold, it can at most be alloyed with only a few hundredth parts of silver, for a larger quantity of that metal would alter the colour of the gold and make it greenish or even white. (*a*)

(*a*) There is another method of determining the quantity of gold in an alloy of copper and gold, but this is only an approximation, and not employed except for trinkets, which should be of the standard of .750. For this purpose the gold is rubbed on a hard black stone, commonly called lydian stone, or touch-stone, (siliceous basalt) so as to form a thin coating on it, of about one-tenth of an inch wide, and two-tenths long, which is moistened with an acid made of 38 parts of nitric acid of the specific gravity of 1.34, and two parts of hydrochloric acid of 1.17, diluted with 25 parts of water. If the trace preserve its yellow colour and metallic brilliancy, the gold is estimated at least as .750; but if, on the contrary, it take the red brown colour of burnt copper, and is in great measure effaced on wiping the stone, the standard is considered inferior, and so much the more so as the trace is more obliterated.

§ 65. A. *Gold* and *Copper.*—Simple cupellation with the proper quantity of lead is all that is required for this assay. The gold may perhaps retain some copper, and possibly also a little lead, but in so small quantity, particularly if care be taken to operate at a temperature of 30° or 32° of Wedgewood, that the error never amounts to the one hundredth part.

B. *Gold, Silver,* and *Copper.*—This analysis is exactly like the gold assay, (§ 65 A.) except that the heat of the furnace must not be raised quite so high, that the silver may not be volatilized. The button is to be weighed after cupellation, and its weight deducted from that of the alloy and of the silver which may have been added, gives the weight of the copper. The proportion of gold is obtained by the weight of the cornet after the action of the acid, and this and the weight of the copper deducted from that of the alloy, gives the proportion of silver. If the alloy originally contain three parts or upwards of silver to one of gold, (which may be known by the proof,) (*a*) there is no need to add any more. When the silver bears a very large proportion to the gold, the latter, after the action of the acid, will not retain the form of the cylinder, but fall to powder.

(*a*) An experienced assayer is satisfied for the proof, with cupelling one part of the alloy with 20 or 24 parts of lead, weighing the button and examining its colour. The weight of the button gives the quantity of copper, and its colour indicates the quantity of silver. If it have the colour of green gold it contains about one-third of silver, if it be scarcely coloured at all, one half; if, when laid by the side of silver it appears as white as that metal, it contains at least two-thirds, and in that case it is enough to add one part more. But the inexperienced will do better to make the analysis as stated, (§ 64.) operating on one part of gold, 20 or 24 parts of lead, and 8 of silver.

Ingots of gold and silver, and of gold, silver, and copper, are met with in commerce; those which contain much silver and little gold are called "*gilded*," they are as white as silver. (*a*)

§ 66. A. *Platina*, *Silver*, and *Copper*.—Pure boiling concentrated sulphuric acid dissolves silver without at all acting on platina. On this property M. d'Arcet has founded a process for effecting a separation of these metals. The alloy (which must contain two parts of silver to one of platina, that the coil may have sufficient tenacity to preserve its form after the solution of the silver) is first to be cupelled in the common method to separate the copper and other oxidable metals, but with rather more lead than is usually employed, and at a higher temperature. Cupelling furnaces not easily affording very intense heats, the quantity of the alloy operated on must be small; it should be such that the button, after cupellation, may weigh about nine grains, and the coil, when the silver is separated, about three grains. If the quantity of silver in the alloy exceed twice that of the platina, a portion of pure gold may be added to bring it to the requisite standard, in preference to making up the deficiency with platina. The cupelled button is to be

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(*a*) I have preferred the French mode of expressing the standard of gold alloys, as being universally applicable, in which fine gold is considered as 1000, and its quantity denoted by the proportion it bears to the whole compound, reckoned in thousandth parts. In England it is computed by carats, an alloy being supposed to be divided into 24 parts, and consequently fine gold, is gold of 24 carats. The standard of English gold coin is expressed by saying it is 22 carats fine, that is that it contains one-twelfth of alloy. Jewellers gold is 18 carats fine, or contains three-twelfths of alloy, which by the French method would be said to be of the standard expressed by .750.

treated exactly as a gold assay, laminated, and coiled up, and the coil put into a glass matrass with pure sulphuric acid, of the specific gravity of about 1.844, and gently boiled for ten minutes, then suffered to cool, the first acid decanted, and replaced by a second portion, and boiled again for seven or eight minutes; when cold, this acid must also be poured off, and the coil washed with a large quantity of distilled water, transferred to a small crucible, and heated red in the usual manner. The weight of the coil, minus that of the gold that may have been added, will now give the proportion of platina in the alloy. M. d'Arcet's memoir may be found in the Annales de Chimie, vol. lxxxix. p. 135.

B. *Platina*, *Gold*, *Silver*, and *Copper*.—If platina be alloyed with a certain quantity of silver and gold, it becomes soluble in nitric acid; hence this offers an obvious method of effecting the analysis.

The copper is first to be separated by cupellation in the common method; the weight of the alloy, minus the weight of the button, gives that of the copper.

The quantity of silver must then be made equal to twice that of the gold and platina, and separated as in the preceding process, (§ 66 A.) by sulphuric acid, whence its quantity will be easily deduced. A fresh portion, about eight grains of the alloy, is then to be taken, and the copper separated as before by the cupel. The button obtained is next to be combined with such a portion of pure gold and of silver, that, (including the quantity of each of those metals already contained in the button,) the gold may be equal to nine-tenths of the weight of the button, and the silver three times that of the gold.

Their union must be effected by passing them at a high temperature on the cupel, with the addition of about 16 grains of pure lead, which will be separated again in the process. The alloy is then to be rolled out into a plate about four inches long, coiled up, and treated with nitric acid of the specific gravity of 1.180 for 20 minutes,—the acid decanted, and the cornet washed, dried, and weighed. The first operation never completely separates the whole of the platina; to effect which the cornet must be passed again on the cupel with three times its weight of pure silver, and the same quantity of lead as before, and the new button treated as the former. These operations must be repeated till the cornet last obtained has exactly the same weight as the one preceding, when it is certain that all the platina has been separated from the gold, the proportion of which in the original alloy, is obtained by deducting from the weight of the cornet that of the gold which has been added. An estimate of the relative proportions of the metals, both in this and the former alloy, must be obtained by preliminary experiments. The hardness and ductility of the alloy, its specific gravity and fusibility, the action of acids, and the manner in which it comports itself on the cupel, and especially a previous assay with the addition of an excess of silver, will enable us to ascertain this, and consequently the proportion of silver and gold to be added either to the alloy, or to the button obtained by cupellation. The quantity of lead necessary for the cupellation must also be regulated by the standard of the alloy.—For more minute details, consult M. Chaudet's Memoir in the second volume of the Annales de Chimie, (new series) p. 264.

DIVISION THE SIXTH.

Analysis of Binary Compounds of the Metals with Sulphur, Iodine, Azote, Phosphorus, and Chlorine.

§ 67. *Sulphurets.* When a metallic oxide is decomposed by sulphuretted hydrogen, water, and a sulphuret of the metal result, and there is no other product; (*a*) consequently the quantity of sulphur in the sulphuret is proportionate to the quantity of oxygen in the oxide.

Sulphuretted hydrogen is formed of one of hydrogen and 15 of sulphur, and water, of 7.5 of oxygen and one of hydrogen; the sulphuret of any metal must therefore contain twice as much sulphur as the oxide of that metal contains oxygen, since one part of oxygen, in combining with a certain quantity of the hydrogen of sulphuretted hydrogen, sets free two parts of sulphur.—Thus 1, the quantity of hydrogen contained in 16 parts of sulphuretted hydrogen, condenses 7.5 oxygen, or half the quantity of sulphur contained in the sulphuretted hydrogen; therefore, an oxide composed of an 100 metal, and 7.5 oxygen, would require 16 parts of sulphuretted hydrogen for its decomposition, and would afford 8.5 of water, and 115 of sulphuret.

§ 68. *Iodides.*—As, when an oxide is decomposed by sulphuretted hydrogen, water and a sulphuret are

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(*a*) All the oxides of the four last sections, are decomposed by sulphuretted hydrogen. Those of iron, zinc, manganese, tin, and antimony require heat. The oxides of the two other sections are not similarly decomposed, in consequence of their very strong attraction for oxygen.

the results, so the compound of hydrogen with iodine, or hydriodic acid, when it effects the decomposition of an oxide, forms water and an iodide. The quantity of iodine in the iodide is, therefore, like that of sulphur in the sulphuret, proportionate to the quantity of oxygen in the oxide.

Hydriodic acid is formed of one volume of the vapour of iodine and one volume of hydrogen, and one volume of hydrogen represents half a volume of oxygen; it follows then, that the quantity of iodine in iodides, is to the quantity of oxygen in oxides, as the weight of a volume of the vapour of iodine is to that of half a volume of oxygen, that is to say, as 8.6864 : 0.553, or as 15.7 : 1.—

§ 69. *Azoturet.* (*a*)—When azoturet of potassium or sodium is put in contact with water, it is decomposed, and ammonia, and oxide of potassium or sodium are formed; — whence if the contrary took place, that is, if ammonia could decompose the oxides, water and azoturets would be the result. The quantity of the azote of azoturets therefore, as in the preceding cases, must be proportionate to the quantity of oxygen in oxides.

Ammonia is formed of three volumes of hydrogen and one volume of azote, and three volumes of hydrogen represent one and a half of oxygen, whence the quantity of azote in the azoturets is to the quantity of oxygen in the oxides, as the weight of a

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(*a*) By this uncouth term, which I use with Thenard and Thomson for want of a better, is meant the compound formed by heating potassium or sodium in dry ammoniacal gas;—hydrogen is at the same time set free, and ammonia obsorbed, so that the compound is at first an ammoniacal azoturet of potassium. By heat, the combined ammonia is expelled and the azoturet left.

volume of azote is to that of a volume and a half of oxygen, or as 0.5839 : 1.

According to this, the azoturets of sodium and potassium must be formed,—the first of 100 potassium and 11.678 azote,—and the second of 100 sodium and 19.852 azote, (a) proportions that differ very slightly from those obtained by another method. (b) (c)

§ 70. *Phosphurets.*—It appears from the experiments of M. Oberkampf, that hydruret of phosphorus decomposes oxide of gold, producing water and a phosphuret. It is reasonable to suppose that it would

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(a) Oxide of potassium (pure anhydrous potassa) is composed of 100 potassium + 20 oxygen, and 1 : 0.5889 : : 20 : 11.678.

Soda is composed of 100 sodium, + 34 oxygen, and 1 : 0.5839 : : 34 : 19.8526.—

(b) One grain of potassium disengages 1.116 cubic inch of hydrogen; consequently the quantity of azote, combined with one grain of potassium, must be $\frac{1.116}{3}$ or about, 112 of a grain, for ammonia is composed of three volumes of hydrogen, and one of azote. When the ammoniacal azoturet of potassium is heated, ammonia only is driven off, and the residuum is a true azoturet of potassium. From these data, therefore, it is composed of potassium 100 + azote 11.34. In the same manner the composition of azoturet of sodium is found to be sodium 100 + azote 19.821.—(Thenard, Vol. II. p. 140.)

(c) When potassium or sodium is heated in pure and perfectly dry ammonia, exactly as much hydrogen is disengaged as would be afforded by the action of the same quantity of the metal on water, and an olive green substance is formed which M. Thenard considers as the azoturet in question.—Ammonia consists of three volumes of hydrogen and one of azote; water, of two volumes of hydrogen and one of oxygen.—When the olive-green substance acts on water, the results are potassa or soda, and ammonia, but for every volume of oxygen that combines with the potassium or sodium, two only of hydrogen are disengaged.—Whence then can the third volume necessary for the reproduction of the ammonia be derived, except from the olive-green substance, which must rather be considered as a triple compound of potassium or sodium, azote, and hydrogen, rather than a pure azoturet.—See Thomson's System of Chemistry, Vol. II. p. 31, fifth edition.

act similarly on the other oxides, if capable of decomposing them, and therefore it may be presumed that the phosphurets follow the same law of composition, as the sulphurets, &c. M. Dulong has found that the phosphuret of copper contains twice as much phosphorus, as the oxide contains oxygen.

§ 71. *Chlorides.*—If there be some ground to doubt the composition of the phosphurets, there is none for questioning that of the chlorides; they are clearly under the same law as the sulphurets and iodides, for on evaporating a hydrochlorate (that is to say a combination of chlorine and hydrogen with an oxide) to dryness, and calcining the residuum, water and a chloride are formed, unless the oxide be not reducible, or having but little affinity for hydrochloric acid, be unable to retain it at high temperatures. Hydrochloric acid is formed of a volume of hydrogen and a volume of chlorine, and a volume of hydrogen gas condenses half a volume of oxygen; the quantity of chlorine in the chlorides therefore must be to the quantity of oxygen in the oxides, as the weight of a volume of chlorine is to that of half a volume of oxygen, or as 4.48 : 1.

Thus, knowing the composition of sulphuretted hydrogen, hydriodic acid, &c. it is easy to find that of the sulphurets and other substances of this class, having a metal for one of their elements, the quantity of sulphur being always proportionate to the quantity of oxygen which the metal requires to assume that state of oxidation to which the sulphuret &c. corresponds. Wherefore, if a certain quantity of a metal absorb 1 of oxygen, it will require 2 of sulphur, 15.7 of iodine, 0.5839 of azote, and 4.48 of chlorine.

CHAPTER THE FOURTH.

Analysis of Oxides.

DIVISION THE FIRST.

Of the Non-metallic Oxides.

§ 72. There are only seven oxides that belong to this class—water, the oxides of phosphorus, carbon, chlorine, and azote, and the deutoxides of chlorine and azote. The five last are gaseous, and have been already treated of, (§ 12. F. G. and § 13. B. C.)

The properties of *water* are too familiar to be confounded with any other substance. Every one knows that it is an uninflammable, colourless, inodorous, and tasteless liquid; that it boils under a pressure of 30 inches of mercury, at 212° Faht. and evaporates without leaving any residuum; and lastly, that it is the solvent of a great number of other substances.

Oxide of Phosphorus is either white or red; it exhales white vapours in the air, like phosphorus, inflames with a very gentle heat, absorbs oxygen, and is converted into phosphorous acid.

DIVISION THE SECOND.

§ 73. *To ascertain the Substances in a Mixture of non-metallic Oxides.*

This problem may be principally referred to the second division of the second chapter, since five of the seven substances it comprehends are gases; the other two will be readily known by the characters detailed in the preceding division.

DIVISION THE THIRD.

§ 74. *To ascertain the nature of a Metallic Oxide.*

If it dissolve in water, and form an acrid caustic solution, which turns syrup of violets green, and tincture of turmeric brown, it must belong to the second division of the third chapter, and its base will be ascertained by the processes there described (*a*).

§ 75. If the oxide be inodorous and reducible by a heat below redness, it must either be an oxide of mercury, or one belonging to the last division; its particular nature will be easily determined, by collecting the metal and examining it. (See the characters of those metals at § 41. B. F. N. § 42. D. F, § 43. D. E.)

§ 76. If the oxide be not reducible by heat, with or without carbonaceous matter, and but very imperfectly by electricity, or any other known agent; if it be insipid, white, and does not, when moistened, turn syrup of violets green, it must be one of the seven oxides contained in the first division (*b*).

A. *Oxide of Silicum,* or *Silica,* is insoluble even with heat, in all acids but the fluoric; calcined with twice its weight of hydrate of potassa, in a silver crucible, a vitreous compound is formed, deliquescent, and consequently soluble in water. The solution,

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(*a*) The alkalies lately discovered in vegetable substances, morphium, picrotoxine, &c. will be described under the head of "proximate elements of vegetables."

(*b*) The characters about to be described, are sufficient to distinguish these seven oxides, independently of the action of the voltaic battery, and reduction by heat, processes which require considerable time.

when concentrated, coagulates with acids; when diluted with water, it is not rendered turbid by acids, but they then produce with it, by evaporation, a transparent jelly.

B. *Oxide of Aluminum*, or *Alumina*, forms with sulphuric, nitric, and hydrochloric acids, very soluble and astringent salts, from which it may be thrown down by potassa, soda, ammonia, and their neutral hydrosulphurets and carbonates. Potassa and soda redissolve the precipitate, but carbonate of ammonia does not. When a saturated solution of sulphate of potassa, or sulphate of ammonia is poured into a concentrated solution of sulphate of alumina, a multitude of crystals of alum are immediately deposited, which, by a second crystallization, affect the form of regular octohedrons.

C. *Oxide of Glucinium*, or *Glucina*.—The sulphate, nitrate, and hydrochlorate of glucina, are deliquescent and very saccharine. The neutral hydro-sulphurets of potassa, soda, or ammonia, do not decompose these salts; but their base is precipitated by the caustic alkalies or their carbonates, and the precipitate is soluble not only in potassa and soda, like alumine, but also in carbonate of ammonia, like zircona.

D. *Oxide of Yttrium*, or *Yttria*, possesses the same properties as glucina, except that it is not soluble in potassa and soda, and its sulphate, far from being deliquescent, requires from 30 to 40 parts of water to dissolve it.

E. *Oxide of Magnesium*, or *Magnesia*, is insoluble in potassa, soda, and carbonate of ammonia. It forms with sulphuric acid a salt which crystallizes in quadrangular prisms; the nitrate and hydrochlorate are deliquescent, and all these salts have a bitter disagreeable taste; their solutions are not disturbed by the bicarbonate, or neutral hydrosulphuret of potassa, soda, or ammonia, but their subcarbonates decompose them. Ammonia precipitates a part of the magnesia from the solutions of its neutral salts, but does not affect the transparency of those which contain much excess of acid; potassa and soda decompose them completely.

F. *Oxide of Zirconium*, or *Zircona.*—When zircona has been heated red, its particles adhere so strongly that they become insoluble in acids. The soluble salts of this oxide have a purely astringent flavour. When reduced to an impalpable powder, or recently precipitated in the state of a hydrate, it is not soluble in either of the caustic alkalies, but carbonate of ammonia dissolves it.

It forms with sulphuric acid an acid sulphate, which on evaporation assumes the appearance of gum, and is rendered turbid by water, provided the acid be not in great excess.

Nitrate of zircona is very soluble, and deposits a gelatinous substance by boiling. The hydrochlorate is a very soluble crystallizable salt, and its solution deposits on boiling a white pulverulent matter. Lastly, zircona is readily thrown down from all these salts by the caustic alkalies and their neutral hydrosulphurets and carbonates; and of these re-agents, carbonate of ammonia alone re-dissolves the precipitate with facility, though the subcarbonates of potassa and soda also dissolve it, but much more difficultly than carbonate of ammonia.

G. *Oxide of Thorinium*, or *Thorina*, is white, insipid, does not change the colour of vegetable blues, and has hitherto resisted all attempts to reduce it to the metallic state. It is infusible in the heat of a forge, and insoluble in water; it readily absorbs carbonic acid at common temperatures, and gives it off again at a red heat. Thorina is very soluble in hydrochloric acid, if previously only moderately heated, but after having been strongly calcined, it is insoluble in it, unless concentrated and boiling. Neutral dilute solutions of hydrochlorate and nitrate of thorina, become turbid by boiling, and deposit the greatest part of the base. The concentrated solution is purely astringent, without any mixture of a sweet, saline, bitter, or metallic flavour. Thorina is insoluble in solutions of potassa or soda, which distinguishes it from silica, alumina, and glucina. As thorina resembles zircona much more than any of the other earths, and their characters are less marked, the following parallel between many of their properties drawn by M. Berzelius, will be useful. (See Annales de Chimie, Vol. V. p. 19. new series.)

Thorina.	*Zircona.*
The taste of its neutral salts is purely astringent.	Precisely similar.
Its sulphate readily crystallizes, and the crystals are decomposed by water.	Not crystallizable, becomes gummy, and after long exposure to a moderate heat, white, opake, and saline; deliquesces in the air, but becomes turbid by the addition of water, unless the solution be very acid; the dry salt is only very partially decomposed by a red heat.

Thorina.	*Zircona.*
The hydrochlorate gives a bulky translucent, gelatinous precipitate by boiling. It is not crystallizable.	The hydrochlorate is precipitated by boiling in the state of a heavy white opake powder. It crystallizes by evaporation.
The nitrate lets fall a gelatineous earth by boiling.	Exactly similar.
The alkaline succinates, benzoates and tartrates, occasion precipitates. The tartrate is soluble in potassa.	Similar.
The citrates occasion no immediate precipitate, but the solution affords one by boiling.	Alkaline citrates occasion no precipitate, and the solution is not made turbid by boiling.
The sulphate is precipitated by oxalate of ammonia.	The sulphate is not precipitated by oxalate of ammonia.
The solution of the sulphate or hydrochlorate, when saturated with sulphate of potassa gives no precipitate.	The solutions of its salts, saturated with sulphate of potassa, are wholly precipitated. If thrown down without heat the precipitate is soluble in water.
Insoluble in hydrate of potassa.	The same.
Soluble in alkaline carbonates.	The same, but in much greater quantity.
By calcination is rendered difficultly soluble.	Becomes insoluble by calcination at a red heat.

§ 77. If the oxide be inodorous, and not reducible by a red heat without the contact of carbonaceous matter, and if the revived metal be fusible or volatile, it must be either oxide of zinc, cadmium, arsenic, tellurium, antimony, tin, bismuth, lead, or copper. The five first are volatile and fusible, the four last fusible only. In either case the metal will be ascertained by the processes already described, and the nature of the oxide thus determined. (Ch. III. Div. II. § 39. et seq.)

The oxides of copper, antimony, bismuth, tin, lead, and arsenic, may also be known as follows:

A. *Oxide of Copper*, by its giving a blue or green solution with nitric acid, into which, if a plate of iron be immersed, it is instantly covered with a coating of copper.

B. *Oxide of Antimony*, is insoluble in nitric, but soluble in hydrochloric acid; the solution is colourless, and is precipitated white by water, and orange yellow by sulphuretted hydrogen.

C. *Oxide of Tin*, like oxide of antimony, is insoluble in nitric, and soluble in hydrochloric acid, and the solution is colourless, and not rendered turbid by water. It is precipitated yellow by the hydrosulphurets, if the tin be in the state of deutoxide, which it always is, if treated with nitric acid prior to its solution in the hydrochloric.

D. *Oxide of Bismuth*, gives colourless solutions both with nitric and hydrochloric acids, from which it is precipitated white by water, and black by sulphuretted hydrogen.

E. *Oxide of Lead*, is soluble in nitric acid, but the red or puce coloured oxide must be first calcined; the solution is colourless, and sweetish, its transparency is not disturbed by water; it forms with sulphuric acid, a white precipitate absolutely insoluble, and a white one also with hydrochloric acid; but boiling in a large quantity of water redissolves the latter, which separates again as the solution cools, in brilliant acicular crystals.

F. *Oxide of Arsenic*, when thrown on burning coals, exhales thick white fumes, which have the smell of garlic or phosphorus: it is soluble in potassa, and the solution precipitates sulphate of copper green; nitric acid separates a white powder from the alkaline solution, and if it be mixed with a hydrosulphuret and an acid, orpiment is deposited. (See C. Appendix.)

G. *Oxide of Osmium* has a strong smell like that of chlorine, a very acrid taste, and when thrown on burning charcoal increases the ignition, like nitre, &c. (§ 42. A.)

H. *Oxide of Manganese*, when fused in a crucible with five or six times its weight of common pearl-ash, forms mineral chamelion, (§ 40. C. *Note.*)

I. *Oxide of Chromium* is of a dark green colour, and gives chromate of potassa, by calcination with an equal weight of potassa or nitre. This salt has a reddish yellow colour, and forms a yellow solution with water; the solution, saturated with nitric acid, precipitates acid nitrate of mercury red, nitrate of silver violet, and acetate of lead bright yellow.

K. *Oxide of Iron* dissolves in hydrochloric acid; from the solution, prussiate of potassa throws down an abundant blue precipitate, or if it be not blue at first, it immediately becomes so on adding a solution of chlorine.

L. *Oxide of Cobalt*, when heated before the blowpipe, or in a crucible, with from 20 to 25 times its weight of borax, forms a blue glass; it gives a rose coloured solution with hydrochloric acid, from which the alkalies throw down gelatinous flocculi of a violet blue colour. The hydrochlorate of cobalt affords a sympathetic ink.

M. *Oxide of Nickel* gives with nitric acid, a grass green solution, from which iron throws down no precipitate. Ammonia first renders the solution turbid, but afterwards restores its transparency, and turns it violet blue.

N. *Oxide of Uranium* is soluble in nitric acid, and the solution possesses the properties described, (§ 41. E.)

O. *Oxide of Cerium* forms with hydrochloric acid, a solution, which affords the phenomena mentioned, (§ 42. C.)

P. *Oxide of Titanium*, after being calcined with potassa and washed, dissolves in hydrochloric acid, and the solution has the properties stated (§ 43. B.)

Q. *Oxide of Molybdena* is blue, and is changed by nitric acid into a white powder, possessing the properties of molybdic acid, (§ 41. H.)

DIVISION THE FOURTH.

Analysis of Mixed Oxides, (a).

§ 78. First heat the mixture in a small portion of distilled water, filter, and wash the residuum till the washings have no effect on infusion of turmeric. This will dissolve the oxides of potassium, sodium,

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(a) Each oxide is supposed to act as if it were insulated, which is not perfectly true, otherwise the problem would be too intricate. It may be added, that it is best to follow this method in all cases, and afterwards submit each product to a fresh and more rigorous examilithium, baryum, and strontium. Next boil the remainder in successive portions of hydrochloric acid, which will dissolve all the oxides, except those of silicium and silver, and perhaps of titanium, chromium, and zirconium, (*a*).

Next put a plate of iron into the solution, which will reduce the oxides of iridium, gold, platina, rhodium, palladium, osmium, (*b*), tellurium, copper, bismuth, antimony, and deutoxide of mercury; separate the precipitate, and dilute the solution largely with water, which will throw down the oxide of arsenic. Filter, and reduce the liquid by evaporation, and immerse a plate of zinc (previously weighed) into it, which will precipitate the lead, cadmium, and tin; then, having decanted the superabundant fluid from these metals, make it *very acid* and add an excess of ammonia, which will precipitate the oxides of cerium, titanium, uranium, chromium, and iron, with the zircona, thorina, glucina, yttria, and alumina; whilst the oxides of nickel, manganese, zinc, and cobalt, with the magnesia and lime, will remain in solution. (*c*) Next filter the liquid, and precipitate the nickel,

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nation. Oxide of molybdena will be omitted, not having yet been thoroughly examined; nor will protoxide of mercury be noticed, as it can only exist in union with acids; nor the oxides of tungsten and columbium, these two metals not having yet been obtained but in the state of acids.

(*a*) It is possible these oxides may not have sufficient cohesion to resist the action of the hydrochloric acid.

(*b*) A great part of the oxide of osmium will be volatilized on heating the mixture with hydrochloric acid; whence to ascertain if it be present, it is better to make the solution in a retort furnished with a receiver, and endeavour to obtain the oxide of osmium from the distilled liquor, as mentioned (42 A.)

(*c*) If the mixture contain both alumina and magnesia, the latter will in part be precipitated with the former.

manganese, zinc, and cobalt, by hydrosulphuret of potassa; then filter again, and add subcarbonate of potassa to the clear solution, which will throw down the lime and magnesia in the state of carbonates. Thus the mixture is divided into eight parts; one solution, one residuum, and six precipitates. Suppose all the substances above mentioned to be present, and let us consider how they may be separated, or at least the presence and nature of each oxide determined.

§ 79. The substances dissolved by the water may be first examined. They are potassa, soda, lithia, barya and strontia, (*a*). Precipitate the two latter by subcarbonate of ammonia, filter, and then add a slight excess of sulphuric acid to the clear solution, evaporate it to dryness, and calcine the residuum in a strong heat. The sulphate of ammonia will be driven off, and the sulphates of potassa, soda, and lithia left. Redissolve them in distilled water, and separate them as directed in a former part of this essay, (§ 44). The carbonates of barya and strontia may then be redissolved in hydrochloric acid, a slight excess of pure ammonia added to the solution, and the barya precipitated by prussiate of potassa; or the two hydrochlorates may be separated (after evaporation to dryness) by boiling them in very strong alcohol. Hydrochlorate of strontia, according to Bucholz, is soluble in 24 parts of that fluid, but hydrochlorate of barya requires 400 parts.

(*a*) A small portion of lime, and even magnesia, may possibly be contained in the aqueous solution, but from the great insolubility of those earths in water, they will be almost wholly found in combination with the hydrochloric acid. Lime requires nearly 800 times its weight of water to dissolve it, magnesia 2000; the other earths may be said to be insoluble.

§ 80. *Residuum left by the Hydrochloric Acid.*—The residuum can only contain silica and zircona, the oxides of chromium and titanium, and chloride of silver. A weak solution of potassa or soda, at the temperature of about 150° or 160°, will transform the chloride of silver into hydrochloric acid and oxide of silver, which will be precipitated, and may then be redissolved by heating it with pure nitric acid, and thrown down again by common salt, which will give a white precipitate, insoluble in nitric acid, but very soluble in ammonia.

The oxides which remain undissolved must be calcined for half an hour with three times their weight of hydrate of potassa, in a silver or platina crucible, and the product treated with a large quantity of water, and filtered. The alkaline solution will contain the silica and the chromium converted into an acid. It must be saturated with nitric acid, and divided into two portions, one of which is to be evaporated, and the other tested with the nitrates of silver, mercury, and lead, which will produce with the chromic acid, respectively, crimson, red, and yellow precipitates. The portion reduced by evaporation will become gelatinous, and the silica may be obtained separate, either by adding an acid to the concentrated solution, or by evaporating it to dryness, and washing the residuum with large quantities of water.

The matter remaining on the filter, will consist of the oxides of titanium and zirconium, and is to be redissolved with heat in hydrochloric acid. Infusion of galls will give a blood red precipitate with the oxide of titanium, by prussiate of potassa it will be thrown down red, by hydrosulphuret of potassa, of a deep green grass, and oxalic acid will form a white flocculent deposit of oxalate of titanium, retaining a portion of the hydrochloric acid. By calcination this will be driven off, the oxalic acid decomposed, and the oxide of titanium will remain uncombined. The zircona will be redissolved by being agitated with a great excess of subcarbonate of ammonia, from which it may be separated again by boiling.

§ 81. *First Precipitate.*—This being composed wholly of reduced metals, they will be recognised by the methods already described, (Ch. III. Div. 2,) remembering that rhodium, by the presence of other metals, may become soluble, not only in aqua regia, but even in nitric acid; it will be right therefore to seek for it both in the residuum and solution.

§ 82. *Second Precipitate.*—This consists only of the oxide of arsenic.

§ 83. *Third Precipitate.*—This precipitate also consisting of metals in the metallic state, like that of No. 81, they will be known by consulting the directions contained in Ch. III. Div. 2.

§ 84. *Fourth Precipitate.*—The oxides of cerium, uranium, and iron with the thorina, glucina, yttria, and alumina, (vide note (*c*) § 78) and perhaps zircona, and the oxides of titanium and chromium, will be found in this precipitate. The oxide of uranium is easily separated. It is only necessary to heat the precipitate, with a solution of subcarbonate of potassa, filter, and add successively an acid and ammonia, each in excess; the carbonates will dissolve the oxide, and the ammonia will throw it down again from the acid. Potassa or soda, with the assistance of heat, will dissolve the glucina and alumina, (*a*) which may be sepa-

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(*a*) If the alumina was combined with magnesia, it will only be dissolved in part by the potassa.

rated from each other by super-saturating the alkaline solution with hydrochloric acid, and then adding a great excess of subcarbonate of ammonia and agitating the mixture; the ammonia will throw down both the earths, but redissolve the glucina. After the oxide of uranium, the glucina and alumina are separated, dissolve the other oxides in hydrochloric acid, evaporate the solution to dryness, and treat the residuum with boiling water, which will immediately precipitate the greatest part of the oxide of titanium, the zircona and thorina. By calcination to redness, the oxide of titanium and the zircona will be rendered insoluble in nitric acid, but the thorina will not be altered, whence it may easily be separated from the other two. (See § 80, for the titanium and zircona.)

The solution by boiling water must then be poured by degrees into a great excess of solution of subcarbonate of ammonia, and the mixture shaken; the yttria, and the zircona (which may have escaped the action of the hydrochloric acid) will remain in solution; next filter the liquid and heat it, by which means it will deposit them again, and they may then be separated by redissolving them in hydrochloric acid, and adding first, neutral hydrosulphuret of ammonia, which will throw down the zircona, and then ammonia, to precipitate the yttria.

It remains to look for the oxides of cerium, and iron; calcine the precipitate, (which may possibly still contain some chromium, titanium, and thorina,) at a red heat, with an equal weight of potassa; if it contain chromium, by digesting this mass in water and letting the liquor stand some time it will become yellow, and when neutralized by an acid, acquire the property of giving a red precipitate with the acid nitrate of mercury, and a violet one with nitrate of silver (a): the precipitate must necessarily contain iron, since this metal was used to separate several of the others, but to know if it formed part of the original mixture, prussiate of potassa must be poured into a portion of the first hydrochloric solution, previously freed from most of the other metals by sulphuretted hydrogen.

Lastly, the oxide of cerium will be distinguished by collecting the portion not acted on by the potassa, dissolving it in hydrochloric acid, evaporating the solution to dryness, and digesting the residuum in boiling water, which will take up the hydrochlorate of cerium, and decompose the hydrochlorates of titanium and thorina, with which it may be mixed. The liquid must then be filtered, the cerium thrown down by tartrate or oxalate of potassa, and the precipitate calcined to separate the oxide. Care must be taken not to heat the oxide of cerium too strongly, lest it be volatilized and lost. (See Thomson's Chemistry, vol. I, p. 408, fifth edit.) (*b*).

§ 85. *Fifth Precipitate.*—This precipitate can only consist of the hydrosulphurets or sulphurets of nickel, cobalt, zinc, and manganese. Boil it with strong nitric acid, two or three times, to dryness, to peroxidate the manganese, which will thus become very

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(*a*) Should it also contain a portion of manganese, which is not unlikely, the potassa after fusion will then have a green colour, and afford the mineral chamelion.

(*b*) In the remaining liquor will be found the magnesia carried down by the alumina, if both were present. It will be combined with a part of the alumina, all the oxide of iron, and possibly a portion of manganese, and may be obtained by adding successively neutral hydrosulphuret of ammonia, and potassa. The first will separate the alumina pure, and the oxides of iron and manganese in the state of hydrosulphurets, and the potassa will throw down the magnesia.

difficult of solution. Add fresh diluted acid to take up the other metals, and when their solution is effected, decant the liquid from the peroxide of manganese, concentrate it to drive off the greater part of the excess of acid, and heat the whole with an excess of caustic potassa, which will throw down the oxides of nickel and cobalt, and redissolve the zinc, which must then be separated from the alkaline solution, as directed (§ 45 C.) The oxides of nickel and cobalt must be redissolved whilst moist, in a solution of pure ammonia in excess, and largely diluted with distilled water; the addition of pure potassa or soda, will then immediately throw down the nickel, which may be separated by the filter, and the cobalt afterwards obtained from the remaining solution by boiling (*a*).

§ 86. *Sixth Precipitate.*—This consists only of the carbonates of lime and magnesia. Dissolve it in nitric acid, concentrate the solution and add a sufficient quantity of sulphuric acid, to convert both the salts into sulphates, evaporate to dryness, and expel the excess of acid by heat. A saturated solution of sulphate of lime in distilled water, will then take up all the sulphate of magnesia and leave the gypsum untouched (*b*). (Phillips. Journal of Science and the Arts, No. 12, January, 1819.)

(*a*) Thomson quotes the following method of Thenard (An. de Chem. vol. L, page 117,) as "the most elegant." The mixture of the two metals is to be thrown down by an alkaline carbonate, and then treated with chlorate of lime. The cobalt is converted into a peroxide insoluble in ammonia, but the nickel is still soluble. Digest in ammonia. The nickel alone is taken up. Drive off the ammonia; dissolve the oxide in nitric acid, and crystallize. (Thomson's Chemistry, fifth edition, vol. 2, page 544).

(*b*) I have had some doubt whether to insert or reject this tedious analysis, but thinking on the whole that it may be useful to the chemical

§ 87. *Of Barya, Strontia, Lime,* and *Magnesia.*

Dissolve them in hydrochloric acid, evaporate the salts to dryness, and boil them in strong alcohol, which will dissolve all but the hydrochlorate of barya. Dilute the alcoholic solution with water, and pour into it a solution of subcarbonate of potassa, to precipitate the strontia, lime, and magnesia. Convert the carbonates into nitrates, and heat them with alcohol; the nitrates of lime and magnesia will be dissolved, and the nitrate of strontia left. Precipitate the lime and magnesia again by subcarbonate of potassa, separate the liquid, and pour weak sulphuric acid, in very slight excess, on the carbonates. The sulphate of lime will precipitate, and the sulphate of magnesia

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student, I determine to let it stand. From its excessively complicated nature, it can hardly be expected to be very correct; it is indeed but a rough outline, which would require details as useless as irksome, to fill it up. I have found it necessary to make several alterations from the original in which some of the directions are inconsistent with the phenomena that occur under the supposed circumstances. Thus, *lead, arsenic,* and *tin,* are enumerated amongst the metals thrown down by a bar of iron. *Manganese* is directed to be precipitated from its solution, *previously made very acid,* by ammonia, and *nickel* and *cobalt,* to be separated by sulphuretted hydrogen. Lead is indeed precipitated in a very beautiful manner in the metallic state, from its saturated solution in nitric acid, by a bar of iron, but I have not succeeded in producing the same effect with the hydrochlorate, the state in which it is supposed to exist in the preceding analysis. I hope the scheme I have adopted may render the processes somewhat less confused and inaccurate, but I know that they are still very imperfect. The case however is so unlikely, I had almost said impossible to occur, in actual practice, that I do not think it worth the time and labour to attempt its more perfect solution. It is rather a curious than a useful problem, a chemical riddle, which may serve to amuse the imagination, but can be attended with no other profit, than what may be derived from the mental exercise it gives rise to.

remain in solution, and must be separated by the filter. (*a.*) The quantity of hydrochlorate of barya, when thoroughly dry, will give that of the barya, and in like manner from the sulphate of lime, sulphate of magnesia, and nitrate of strontia are obtained the

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(*a*) Dr. Thomson employs the following method to separate lime and magnesia. Dissolve the mixture of the two earths in hydrochloric or nitric acid, then add to the solution a quantity of sulphuric acid capable of saturating them both; evaporate the liquid to dryness, and expose the residual mass to a heat sufficient to expel the excess of acid. Digest the dry mass in water, and pour a little alcohol into the solution to diminish the solubility of the sulphate of lime; by this means the sulphate of magnesia is obtained in solution, while the sulphate of lime remains behind in the state of a white powder. Dr. Thomson does not consider this method as absolutely precise, but the error is very trifling if the experiment be rightly conducted. (Annals of Philosophy, Nov. 1818.)

Mr. Phillips has lately proposed the following, which seems to me the best method, or rather the only perfect one hitherto suggested, for separating these two earths. I insert it in Mr. Phillips's own words taken from his paper on this subject in the Journal of Science and the Arts. vol. VI, page 317.

"To the muriatic or nitric solution of lime and magnesia, add sulphate of ammonia in sufficient quantity, evaporate the mixture gradually to dryness, and then heat it to redness till it ceases to lose weight, by the volatilization of the muriate or nitrate of ammonia formed. Note the weight of the mixed salt, reduce it to powder, and wash it with a saturated solution of sulphate of lime, till all the sulphate of magnesia appears to be dissolved; dry the sulphate of lime left, and by deducting its weight from that of the mixed sulphates, the quantity of sulphate of magnesia dissolved will appear.

"I prefer sulphate of ammonia to sulphuric acid, because the operation is not only less disagreeable, but the contents of the crucible are not so subject to spirt out of it, and occasion loss.

"If it be required to verify the experiment, by ascertaining the quantity of sulphate of magnesia dissolved, this may be effected by two modes; first, by noting the quantity of solution of sulphate of lime employed, and ascertaining how much carbonate of lime a similar quantity of it yields by carbonate of soda; all excess of weight quantity of bases which enter into the composition of those salts.

100 parts of hydrochlorate of barya contain	74	barya
———— sulphate of lime . . .	41.5	lime
———— sulphate of magnesia . .	33	magnesia
———— nitrate of strontia . .	48.6	strontia.

§ 88. *Of Alumina, Glucina, Yttria, Zircona, Silica, Oxide of Iron, Oxide of Manganese, and Oxide of Chromium.*

Silica, being the only one of these substances insoluble in hydrochloric acid, is easily separated (*a*); then add neutral and quite pure hydrosulphuret of ammonia to the solution, to throw down the alumina and zircona; the oxides of iron, manganese, and chromium, (*b*) with the yttria and glucina will

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obtained by similar means from the solution employed, will, of course, be owing to carbonate of magnesia, and by this the quantity of sulphate dissolved may be discovered.

"Secondly, the quantity of sulphate of magnesia dissolved, may be known by comparing the quantities of sulphate of barytes obtainable from the pure solution of sulphate of lime, and from that of the two sulphates.

"In order to shew whether this method may be relied upon with any degree of confidence, I added one grain of sulphate of lime to about four ounces of a mixed solution of sulphate of magnesia and sulphate of lime; not a particle appeared to be dissolved, the sulphate readily subsiding, whereas, a similar quantity of solution of sulphate of magnesia appeared to dissolve the sulphate of lime, as readily as if no sulphate of magnesia had been present."

(*a*) Possibly the oxide of chromium and the zircona may be dissolved, which must partly be the case if the oxides have been calcined at a red heat. In that event, the residuum must be treated as directed, (§ 80.)

(*b*) It is essential that the hydrosulphuret be quite free from any admixture of carbonate.

remain dissolved. To obtain them, add potassa in excess, filter the new solution, heat it with hydrochloric acid to drive off the sulphuretted hydrogen, and mix it with ammonia. The potassa will precipitate the yttria but retain the glucina in solution, and the latter will be disengaged from the hydrochloric acid by the ammonia.

The silica, yttria, and glucina being separated, digest the precipitate of alumina, zircona, oxides of iron, manganese, and chromium, in solution of potassa at a temperature of about 160° to dissolve the alumina, which may then be separated by supersaturating the solution with an acid and adding ammonia.

To obtain the zircona, dissolve the four remaining oxides afresh in hydrochloric acid, and agitate the solution with a great excess of subcarbonate of ammonia, which will throw down the oxides of iron, manganese, and chromium, but dissolve the zircona, (§ 80) and it may be separated again from the solution by simply boiling it. If it be coloured, it must be purified by redissolving it in hydrochloric acid, and adding very cautiously, drop by drop, a solution of hydrosulphuret of ammonia, till it ceases to give a black precipitate, then filter and throw down the zircona by caustic ammonia. To separate the oxides of chromium, iron, and manganese, calcine them with an equal weight of nitrate of potassa, in a platina crucible; the chromium will thus be acidified and unite to the potassa; oxide of manganese also will combine with the alkali, but be wholly separated again, with the iron, by throwing the mass into water, and exposing the liquor to the air, whilst the chromate of potassa will remain in permanent solution. To extract it, saturate the solution with nitric acid, add nitrate of mercury, and calcine the chromate of mercury produced; the oxide of chrome will remain in the retort. The oxides of iron and manganese must be separated as already directed (§ 55 Note.)

§ 89. *Barya, Strontia, Lime, Magnesia, Glucina, Yttria, Alumina, Zircona, Silica, Oxides of Iron, Manganese, and Chromium.*

This analysis is in some degree composed of the two preceding. Thus the mixture is to be treated with hydrochloric acid, and the solution with hydrosulphuret of ammonia. The acid dissolves all the bases, except the silica; the alumina and zircona, with the oxides of iron, manganese, and chromium, are precipitated by the hydrosulphuret and may be separated from each other as already directed, (§ 88.)

Next, pour an excess of hydrochloric acid into the filtered liquor, and heat it, to expel the sulphuretted hydrogen, after which add successively ammonia and solution of subcarbonate of potassa, which will give two precipitates, the first consisting of glucina and yttria, the second of the carbonates of barya, lime, strontia, and magnesia, the proportions of whose bases are to be determined in the same manner as if they were uncombined (§ 87.) For the glucina and yttria, heat the solution of potassa, which dissolves the former, and leaves the latter, and the glucina may then be obtained in the usual manner, by saturating the solution with an acid, and adding ammonia.

Analysis of Stones.

§ 90. Stones are natural combinations of various oxides, sometimes containing as accessary principles, acids, combustibles, and salts. They are chiefly composed of silica, alumina, lime, magnesia, and the oxides of iron and manganese. They sometimes, but rarely, contain glucina, yttria, zircona, potassa, soda, and oxide of chromium; more rarely barya and oxide of nickel, and still more so lithia and the other oxides. Silica and alumina are their most frequent and abundant elements.

§ 91. Most stones are too hard to be readily acted on by acids; they must first, therefore, be ground in an agate or flint mortar, in portions of eight or ten grains at a time, till reduced to an impalpable powder (*a*); then weigh off 50 or 100 grains and put them in a silver or platina crucible, with three or four times their weight of hydrate of potassa, or soda; cover the crucible with its lid, and expose it by degrees to a red heat, and after the matter is fused, or at least has become pasty, which will require about three-quarters of an hour, withdraw it from the fire, and when cool, pour water on the mass, and heat it again; repeat this operation several times, decanting each portion into a capsule with the greatest care not to lose an atom, till the whole is detached from the crucible. Hydrochloric acid must then be added by degrees, and

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(*a*) When the stone is very hard it is well to heat it red, and plunge it in water; by these means its pulverization is much facilitated. It must be ascertained that it loses nothing by this calcination, or an account kept of what it may lose.

the mixture stirred to assist the action of the acid.—When the solution is complete, evaporate it to dryness, (a) to volatilize the excess of acid, boil the residuum in eight or ten times its bulk of water and filter; the silica will be collected on the filter. The other bases will be obtained from the filtered liquor (which must be mixed with the washings) in the usual manner. (§ 89.)

A preliminary trial should be made to ascertain the constituent principles of the stone, and a separate one to determine their proportions.

§ 92. If the sum of the weights of the several ingredients obtained by the analysis does not equal within a few hundredth parts the weight of the stone employed, it probably contains an alkali. To ascertain this, fuse a certain quantity of the stone with boracic acid, or nitrate of barya, diffuse the mass through water, and treat it with hydrochloric acid, then evaporate the solution to dryness to drive off the excess of acid, pour water on the residuum, filter the liquor to separate the silica and boracic acid, deposited during the evaporation, and add subcarbonate of ammonia, which will decompose the salts of lime, magnesia, alumina, &c.; filter again to separate the precipitate thrown down by the subcarbonate of ammonia, evaporate the solution to dryness, and calcine the residual mass in a strong heat in order to volatilize the hydrochlorate of ammonia formed in the process.—The new residuum will consist of the potassa, soda, or lithia, combined with hydrochloric acid. It must

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(a) When the evaporation is nearly finished the heat must be carefully regulated, and the matter stirred incessantly, to prevent any of it spirting out of the capsule.

be decomposed by diluted sulphuric acid; the saline mass dissolved in water, and the alkaline sulphates separated in the manner already directed (§ 44.); or, the dry hydrochlorate may be first digested in strong alcohol, which will dissolve the hydrochlorate of lithia, and then the remainder converted into sulphates, and separated by crystallization.

§ 93. If, notwithstanding the loss of weight, no alkaline matter can be found in the stone, it may probably contain an acid. This must be determined by submitting it to various tests and its quantity accurately ascertained. (*a*)

§ 94. Suppose it were required to analyse a specimen of aqua-marine, which, according to M. Vauquelin, is composed of 69 parts of silica, 13 alumina, 16 glucina, one of oxide of iron, and 0.5 of lime.

A. The silica being separated as just directed, pour an excess of ammonia into the solution, which will throw down the alumina, glucina, and oxide of iron. Collect the precipitate on a filter, and wash it till the washings cease to turn syrup of violets green.

B. The washings being mixed with the filtered solution, add to it subcarbonate of potassa, to throw down the lime, which, being washed, dried, and strongly calcined, gives the whole of the lime in the aqua-marine.

C. Scrape off the precipitate (A.) in its gelatinous state from the filter with an ivory knife, and heat it in a capsule with a great excess of solution of caustic potassa, which will dissolve the glucina and alumina,

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(*a*) This is a case of very rare occurrence: hitherto only the fluoric and phosphoric acids have been found in the hard stones employed as gems.

but have no action on the oxide of iron. After boiling 15 or 20 minutes, remove the capsule from the fire, and when cooled to about 100°, filter the liquor, (*a*) and wash the filter as long as it gives any indication of an alkali; collect the oxide of iron, dry, calcine, and weigh it.

D. Saturate the alkaline liquor with nitric or hydrochloric acid, and add an excess of ammonia to precipitate the whole of the glucina and alumina.

E. Dissolve the precipitate of the last experiment in weak hydrochloric acid, and pour the solution by degrees into a large excess of solution of carbonate of ammonia, shaking the vessel after the addition of each portion. The glucina will be dissolved, and the alumina deposited in white flakes, which may be collected on a filter, and its quantity ascertained by weighing it, after it has been washed, dried, and calcined.

F. Lastly, to obtain the glucina and finish the analysis, boil the solution effected by the carbonate of ammonia, which will volatilize that salt and throw down the glucina; collect it on a filter like the alumina, and, when washed, dried, and calcined, ascertain its weight.

§ 95. The preceding method differs a little from that described, (§ 89.) where, after separating the silica, hydrosulphuret of ammonia is added to the liquid instead of ammonia, which is preferable when the stone contains both magnesia and alumina; for if ammonia be poured into a mixed solution of aluminous and magnesian salts, the precipitated alumina

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(*a*) If the liquor be so caustic as so burn holes in the paper, dilute it with water.

will carry down a part of the magnesia, and the two bases cannot easily be separated, but by dissolving them in an acid, and adding a hydrosulphuret. (a) But if the solution contain only magnesia, without any mixture of alumina, and be sufficiently acid, the ammonia will not throw down a particle of magnesia. In all other respects the analysis is easily performed in either case.

Analysis of Clays.

§ 96. Clays being formed at most of silica, alumina, carbonate of lime, oxide of iron and water, may be analysed by processes similar to those already described. The silica is to be extracted as in hard stones, then ammonia will precipitate the alumina and oxide of iron from the acid solution; after which, filtering the liquid and adding subcarbonate of potassa, we obtain a fresh precipitate of carbonate of lime. Solution of potassa will separate the oxide of iron and alumina in the usual manner. The quantity of water may be found by calcining a portion of the clay strongly in a platina crucible, deducting from its loss of weight after the operation that of the carbonic

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(a) These bases may indeed be separated by the alternate action of caustic potassa and hydrochloric acid, precipitating the mixed residuum left by the alkali, and re-dissolved by the acid, by ammonia, and again treating it with caustic potassa. This process requires several repetitions. The potassa in each process dissolves a portion of the alumina, so that its quantity in the acid solution continually diminishing, it carries down less and less magnesia each time when precipitated by the ammonia.— Thus all the alumina is at last obtained in combination with the potassa and all the magnesia with the acid and ammonia, and may be separated by the usual methods.

acid of the carbonate of lime, which will be decomposed in the process, and will be known from the quantity of lime obtained in the analysis; 100 parts of lime indicate 78 of carbonic acid.

DIVISION THE FIFTH.

Analysis of Metallic Oxides.

§ 97. Some oxides, those of mercury and of the last division, for instance, are readily reduced by heat; the proportion of their elements may, therefore, be determined by its agency alone.

A. Dry the oxide completely, either by exposing it to the temperature of boiling water, or by placing it in a basin by the side of another containing recently fused and still hot chloride of calcium (muriate of lime) under an exhausted receiver.

B. Introduce it into a perfectly dry small retort, (previouly weighed) taking care that none of it adhere to its neck, and ascertain the weight of the whole with great accuracy; not less than 150 grains of the oxide should be employed, and it is better to use even 1000, if convenient.

C. Adapt a tube to the retort, so bent as to pass under and rise nearly to the top of a receiver, inverted over and full of water.

D. Bring the retort gradually to a cherry-red heat, that no portion of the oxide may be carried over.

E. Collect the air of the vessels as well as the oxygen, keep up the fire, till the decomposition is complete, and leave the tube, attached to the retort, immersed in the gases till the whole has acquired the temperature of the atmosphere. (a)

F. Withdraw the tube cautiously that no air may enter the receiver, and measure the quantity of gas it contains, which will exactly represent the volume of oxygen of the oxide; then, having wiped the retort quite clean and dry, take out the cock and weigh it.—Deducting this weight from that of the retort and oxide, the weight of the metal, provided it be not volatile, is obtained, and the volume of gas will give the weight of the oxygen.—If the analysis be correct the sum of these weights will exactly equal that of the oxide operated on.

§ 98. Though the metals of the last division have so slight an affinity for oxygen that they part with it below a red heat, those of the second and third have so great an attraction for that principle, that they decompose water, setting free the hydrogen, and this property affords a very simple and exact method of knowing the quantity of oxygen in the metallic oxide which is formed. For this purpose the metal must be weighed and completely oxidated, and the whole of the hydrogen disengaged, collected; from the volume of which is deduced that of the oxygen, and from this its weight. The operation may be performed in two ways.—When the metal belongs to the second division, if potassium, for instance, press eight or ten grains of it into a small tube of glass (closed at one end) so as completely to fill it, and weigh the tube correctly,

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(a) By these means as much gas returns into the retort after the operation, as was expelled from it at the beginning.

both empty, and after it is filled; then, closing the tube with a plate of glass, bring it under a receiver full of water, and slip the glass plate aside with the finger, when the metal will instantly act on the water and decompose it, disengaging hydrogen gas, which will be collected in the receiver, and the potassa formed will remain dissolved in the water.

If the metal belong to the third division, water alone is not sufficient; its action must be assisted either by sulphuric or hydrochloric acid. Put the metal into a small matrass placed on a furnace, (a) and to its neck adapt a tube of safety and another tube so bent as to pass under a receiver full of water. The apparatus being thus arranged, pour a sufficient quantity of acid of the proper strength, through the safety tube into the matrass, and apply heat if necessary, adding fresh portions from time to time till the metal is completely dissolved. (b) Then fill the matrass as well as the tube of communication with water. Thus all the air of the vessel and the hydrogen gas will be collected in the receiver, and it only remains to ascertain by the eudiometer the quantity of hydrogen, (c) and from this to deduct the volume and weight of the oxygen absorbed by the metal.

(a) Five hundred grains of zinc, iron, or tin, at the least must be employed; as manganese is difficult to obtain, we may operate on one third of the quantity of that metal.

(b) For zinc, manganese, and iron we may employ sulphuric acid diluted with six times its weight of water; for tin we must use concentrated hydrochloric acid and apply heat.

(c) This is done by passing an electric spark through a mixture of 100 parts of the gas and 60 of oxygen, in the eudiometer over mercury. Two-thirds of the absorption represent the quantity of hydrogen in 100 parts of the gas. (§ 28. B.)

§ 99. Several metals absorb oxygen below a red heat and acquire a certain degree of oxidation. Potassium and sodium are thus reduced to the state of peroxide; arsenic, to that of deutoxide. If a portion of one of these metals be heated by a spirit lamp in an excess of oxygen gas in a small bent tube over mercury, the volume of the residual gas being deducted from the original volume, that of the oxygen absorbed, and consequently its weight, will be ascertained. When the experiment is made on potassium or sodium, the metal must be placed in a small capsule of platina or silver, to prevent the tube being broken by the intensity of the heat, but arsenic may be placed directly on the glass. By this method also may be determined the quantity of oxygen gas, which the oxide of barium requires to pass to the state of deutoxide, and it probably would be equally calculated to determine the proportions of the elements of oxide of tellurium on account of its volatility.

§ 100. Nitric acid acts on most metals, converting some of them into oxides which it is incapable of dissolving, others into oxides which it dissolves, but is separated from them again by a red heat, without the oxides themselves being volatilized, or suffering any change liable to render the experiment inaccurate. To the first class belong tin and antimony; in the second are zinc, iron, bismuth, copper, lead, cadmium, &c. Hence, by means of this acid, may be determined how much oxygen these metals require to pass to a certain degree of oxidation; namely, the six first to that of peroxide, and lead and cadmium to the state of protoxides.

Put about 250 grains of the metal, in filings, into a weighed platina crucible, and pour on it by degrees pure nitric acid, of such strength, that the action may be moderate. When all the metal is dissolved, or compleatly oxidated, (which is known by no more red fumes being produced on applying heat), evaporate the liquid to dryness, taking care that none of the matter be projected out of the crucible, which must then be covered and heated red, for about half an hour (*a*); then suffer the crucible to cool and weigh it. From the increase of weight, the quantity of oxygen fixed by the metal is obtained.

§ 101. The quantity of oxygen in a metallic oxide may also be ascertained, by dissolving a given quantity of the metal in an acid, and precipitating the oxide by an alkali, or alkaline subcarbonate. In this case the metallic oxide must be wholly precipitable by the alkali, insoluble in that substance, and not altered by the action of heat or air.

§ 102. But the most general process is founded on a law observed in the composition of salts; namely, that the quantities of bases that saturate the same weight of acids, contain the same weight of oxygen. Suppose it were required to find how much oxygen is united to the barium in a hundred parts of sulphate of barya. The quantity of acid in that salt must be first ascertained, and experiment shews it to be 34 per cent.

Suppose besides, that sulphate of lead consists of 137 lead, 52.5 sulphuric acid, and 10.5 oxygen.

Since 34 parts of sulphuric acid saturate 66 parts of barya, 52.5 parts would saturate 101.9, and consequently by the law, that quantity of barya contains the same weight of oxygen, as 147.5 of oxide of lead,

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(*a*) Antimony must be heated 'till the oxide is quite white.

or 10.5. Therefore 101.9 : 10.5 : : 66 : 6.8=the quantity sought. For this law and the canon founded on it, we are indebted to Berzelius; it is not however wholly free from exceptions.

In enquiries of so delicate a nature as those on the composition of the oxides, we should always endeavour to confirm the result of our experiment by another differently conducted; and our confidence in them will be strengthened, in proportion as the methods are varied by which we obtain them. (Appendix. D.)

DIVISION THE SIXTH.

To ascertain the nature of a Mineral Acid.

§ 103. The distinguishing properties of the gaseous acids, namely, carbonic, sulphurous, chloro-carbonic, fluoboric, fluosilicic, hydro-chloric, hydriodic, hydro-sulphuric, or sulphuretted hydrogen, have been given already, (§ 11 and 12.) It remains to detail the characters of the following:—boracic, phosphoric, phosphorous, hypophosphorous, sulphuric, nitric, nitrous, pernitrous, arsenic, arsenious, antimonic, antimonious, chromic, molybdic, tungstic, columbic, chloric, iodic, chloriodic, hydrofluoric, and selenic. Of these some are solid, the rest liquid, and three of them are coloured: viz. tungstic acid, which is yellow, chromic purplish, and nitrous acid (when its specific gravity is between 1.114 and 1.24), orange yellow.

§ 104 *Boracic Acid* is solid, fusible, and vitrifiable at a red heat, fixed, almost tasteless, and faintly reddens litmus; it is sparingly soluble in water, falling down in the form of lamellar crystals from a saturated hot solution, as it cools. Lastly, it unites to potassa and soda, and produces with these alkalies very soluble borates, from which it may be precipitated in a crystalline form by most of the other acids. Boracic acid tinges the flame of alcohol of a beautiful green colour.

§ 105. *Phosphoric Acid* is solid, fusible and vitrifiable, like boracic acid, but is volatilized at a high temperature; it strongly reddens litmus, is very caustic, deliquescent and uncrystallizable; it is decomposed by charcoal, and affords phosphorus at a heat very little exceeding a dull red.

§ 106. *Phosphorous Acid.*—When a solution of phosphorous acid is much reduced by evaporation, it becomes syrupy, and on cooling, assumes a solid crystalline form. It exhales a disagreeable fetid odour, and strongly reddens infusion of litmus. When heated, it yields penetrating white vapours. If heated in a retort, hydruret of phosphorus is given off, which inflames spontaneously on coming in contact with the air; when ignited with charcoal it is decomposed, and yields phosphorus.

§ 107. *Hypophosphorous Acid* does not exist naturally, but is formed whenever a phosphuret is acted on by water; phosphoric acid and hydruret of phosphorus being produced at the same time. It is liquid, has a strong acid taste, and reddens litmus deeply. It is not crystallizable; it is decomposed by heat in close vessels, and the products are hydruret of phosphorus, phosphorus, and phosphoric acid. It is soluble in water in all proportions; it takes oxygen from many of its combinations.

The hypophosphites are remarkable for their solubility; there is not one which is insoluble. The hy pophosphites of potassa, soda, and ammonia are soluble in alcohol. The first of these is even more deliquescent than hydrochlorate of lime.

The hypophosphites are decomposed by heat, and afford the same results as are obtained by the decomposition of the acid.

§ 108. *Phosphatic Acid.*—I omit the description of this acid, because it seems almost certain, that it is merely a mixture of the phosphoric and phosphorous acids, since it is always converted into those two substances whenever it is combined with salifiable bases.

§ 109. *Sulphuric Acid*, in a state of absolute purity, is solid, but is seldom seen in that form, nor does it retain it at a temperature exceeding 66° of Faht. It is inodorous; from a very dilute solution of nitrate or hydrochlorate of barya, it throws down a white precipitate, insoluble in excess of acid; when combined with potassa or soda, and calcined with charcoal, it yields a sulphuret, which produces, when moistened, the taste and smell of rotten eggs.

§ 110. *Nitric Acid* is easily known by the red nitrous vapours which are evolved by its action on copper filings. If the acid be very much diluted, it is necessary to heat it, to promote the effect.

§ 111. *Nitrous Acid.*—Its characters are very marked. When brought in contact with the air, or other gas, it gives off red vapours. Deutoxide of azote indeed does the same in atmospheric air by seizing its oxygen; but in the other gases, as carbonic acid for instance, it remains colourless. By itself, the deutoxide of azote, is not acid, and it always exists as a gas

§ 112. *Pernitrous Acid* is formed, according to Gay Lussac, when a strong solution of potassa is left a long time in contact with the deutoxide of azote; crystals of pernitrite of potassa are produced. This acid cannot be obtained separate; whenever the pernitrite is decomposed by a stronger acid than its own, the latter is changed into deutoxide of azote which flies off, and common nitrous acid which remains in solution.

§ 113. *Arsenic Acid* is solid, reddens litmus, is caustic, deliquescent and uncrystallizable, like the phosphoric. It is decomposed by a strong heat into oxygen and arsenious acid, and when ignited with charcoal in a retort, metallic arsenic sublimes and condenses in the neck, in a crystalline form.

§ 114. *Arsenious Acid* is a white, brittle, compact substance, of a glassy appearance; it has a sharp acrid taste, which at last leaves an impression of sweetness, and is a virulent poison. It reddens vegetable blues, and dissolves very sparingly in cold water, but more readily in hot. Heated on charcoal by the blowpipe, it emits an alliaceous smell. When mixed with quicklime, and the mixture heated in a glass tube, a beautiful phenomenon may be observed. At a certain temperature the mixture becomes ignited, the combustion gradually pervading the whole mass. At the same time a quantity of metallic arsenic sublimes. A portion of the arsenious acid parts with its oxygen to another portion, which thus becomes arsenic acid, and combining with the calcareous earth, forms arseniate of lime. The experiment was made by Dr. Wollaston. (Thomson's Chemistry, Vol. II. p. 115. 5th edition.)

§ 115. *Antimonic Acid* is a solid, of a straw colour;

it is nearly insoluble in water, but reddens vegetable blues. At a red heat it gives out oxygen, and is converted into antimonious acid. It unites with bases, and forms antimoniates.

§ 116. *Antimonious Acid* is solid, of a fine white colour; it is insoluble in water, and has no action on atmospheric air, or oxygen gas; it is volatilized, but not decomposed by a strong heat. When in the state of hydrate it reddens tincture of litmus. It combines with bases, and forms salts, that may be denominated antimonites.

§ 117. *Chromic Acid.*—Its colour is purplish; when calcined, it passes to the state of green oxide. It forms neutral soluble chromates with potassa and soda, of a yellow colour, which precipitate acid nitrate of mercury red, nitrate of silver crimson, and nitrate of lead bright yellow.

§ 118. *Molybdic Acid* is solid, white, almost tasteless, reddens tincture of litmus faintly, fuses when heated in close vessels, and crystallizes on cooling; in open vessels it volatilizss in white vapours; it is sparingly soluble in water, and is thrown down from it in the state of blue oxide by a plate of zinc or tin. With potassa, soda, and ammonia it forms molybdates, from which it is separated as a white powder by most of the acids.

§ 119. *Tungstic Acid* is solid, yellow, insipid, does not redden litmus, is infusible and insoluble in water. It is very soluble in potassa, soda, and ammonia, and forms with these alkalies colourless tungstates, which are decomposed by the sulphuric, nitric, and hydrochloric acids, and a white substance is thrown down, which becomes yellow by boiling in either of these acids. Tungstate of ammonia is decomposed, and gives the yellow tungstic acid by heat alone.

§ 120. *Columbic Acid.* (See Columbium, § 43. C.)

§ 121. *Chloric Acid* is not found in nature, either free, or in combination. It is formed whenever a solution of an alkali or alkaline earth is placed in contact with chlorine. It is a colourless, inodorous liquid, with a very acid taste. It first reddens litmus paper, but after a few days entirely destroys its colour. It has no action on sulphate of indigo, nor is it altered by light; by a gentle heat it may be concentrated, but a high temperature decomposes it, one portion evaporates, and the rest is converted into chlorine and oxygen. It is also decomposed by sulphuretted hydrogen, and by the hydrochloric and sulphurous acids, but not by the nitric. It does not throw down silver or any other metal from its solution.

The chlorates of potassa, soda, &c. when thrown on ignited coals, occasion a vivid ignition; and when heated in glass retorts, they give off oxygen gas, and are reduced to the state of chlorides.

§ 122 *Perchloric Acid.*—The existence of this acid, which was first announced by Count Stadion of Vienna, was not immediately considered as established, but the accuracy of his views have been since confirmed by Sir Humphry Davy. It is obtained by acting on chlorate of potassa by concentrated sulphuric acid, in the proportion of two of the acid to one of the salt; deutoxide of chlorine is disengaged, and a salt is left, which, when washed with small portions of cold water 'till it passes tasteless, and separated by the filter, amounts to $\frac{28}{100}$ of the chlorate employed.

It is possessed of the following properties:—it is perfectly neutral, undergoes no change by exposure to the air, is readily soluble in boiling water, but not so in cold; its taste is similar to that of hydrochlorate of potassa; it crystallizes in the form of elongated octohedrons. It detonates feebly when triturated in a mortar with sulphur; at the temperature of about 400° Faht. it fuses, gives off oxygen, and is converted into chloride of potassium. The products per cent. are,

Potassium . . .	28.49	54.08
Chlorine . . .	25.59	
Oxygen		45.92
		100.00

28.49 of potassium require 5.819 of oxygen to become potassa, which deducted from 45.92 leaves 40.1 that were combined with the chlorine to form the perchloric acid.

The new salt gradually heated with an equal weight of sulphuric acid, diluted with one third water, at first gives off only water, but as the heat increases white vapours appear, which condense in the receiver into an acid liquid, consisting of the perchloric acid, with a mixture of sulphuric and hydrochloric acids; the first must be separated by barya water, the second by oxide of silver. Perchloric acid may also be obtained, by submitting an aqueous solution of deutoxide of chlorine to voltaic electricity. Perchloric acid cannot exist in an insulated form; water or a base must be present: it is colourless, not possessed of any peculiar odour, reddens infusion of litmus, but does not destroy vegetable colours.

It is not decomposed by light, and may be concentrated by a gentle heat. It rises in vapour at about 284°, and is not decomposed by either sulphurous acid or sulphuretted hydrogen, which distinguishes it from chloric acid. It does not give any precipitate with nitrate of silver.

The salts it forms with the alkalies and other bases are not decomposed by the most powerful acids, at the temperature of boiling water.—(Annales de Chimie, tom. viii. p. 411.)

§ 123. *Iodic Acid* fuses at a heat rather below that of boiling olive oil, and is decomposed into vapour of iodine and oxygen; its taste is very sharp and astringent. When dissolved in water, sulphurous acid and sulphuretted hydrogen instantly separate iodine, as does hydriodic acid, whose iodine is deposited at the same time. Sulphuric and nitric acids combine with it, without effecting any change. It forms with solution of silver a white precipitate, soluble in ammonia. It unites with all bases, and forms salts of little solubility. The iodates of potassa and soda fuse on burning coals, in the manner of nitre. Iodate of ammonia fulminates by heat.—(Gay Lussac.)

§ 124. *Chloriodic Acid.*—Thenard calls this chloride of iodine; the English chemists more properly consider it as an acid, containing, like chloric and iodic acids, two supporters of combustion. Chloriodic acid formed by the sublimation of iodine in chlorine in great excess, is of a bright yellow colour; when fused it becomes of a deep orange; and when rendered elastic, it forms a deep orange coloured gas. When heated with iodine it combines with a further portion of that substance. It is deliquescent; its solution in water, when deprived of excess of chlorine and diluted, is colourless, very acid, and slowly discharges the colour of sulphate of indigo; it is capable of dissolving large quantities of iodine, when it becomes orange yellow, and the more so as the quantity of iodine dissolved is greater. When a pure colourless solution of chloriodic acid is poured into a solution of hydrochlorate of barya, iodate of barya precipitates, and the liquor becomes very acid: if the acid be coloured, iodine is also thrown down. The colourless acid solution precipitates a white powder from a strong solution of ammonia, which detonates feebly by heat; if highly coloured chloriodic acid be employed, the powder that falls down, is black, and detonates with much greater force, and with the slightest touch or motion. It is a compound of iodine and azote.

M. Gay Lussac supposes that chloriodic acid is decomposed when it is dissolved in water; in that case one of two things must happen, either the chlorine must combine with the oxygen of the water, and form oxide of chlorine, whilst its hydrogen forms with the iodine hydriodic acid, or hydrochloric and iodic acids must be produced. The former is improbable, for oxide of chlorine immediately decomposes hydriodic acid and precipitates iodine, which is afterwards redissolved by the chlorine set free.

To ascertain if the latter be the case, Sir Humphry Davy distilled the solution at different temperatures, and collected the products, but always obtained the same fluid, whence he infers as most probable, "that the acid property of the chloriodic compound depends upon the combination of the two bodies; and its action upon solutions of the alkalies and the earths, may be easily explained when it is considered that chlorine has a greater tendency than iodine to form double compounds with the metals, and that iodine has a greater tendency than chlorine to form triple compounds with oxygen and the metals." (Philosophical Transactions, 1814, p. 501.)

§ 125. *Hydrofluoric Acid* is the only acid that attacks glass, which it corrodes and dissolves the silex, forming with it a peculiar gas, the fluosilicic.

§ 126. *Selenic Acid* has a pure acid flavour, and leaves a slight sense of burning on the tongue.—It reddens vegetable blues.—It is very soluble in cold water, and in hot still much more so.—A saturated hot solution of selenic acid in water, crystallizes on cooling *rapidly*, in small grains, and if *slowly* cooled, in striated prisms. By spontaneous evaporation the solution gives star-like clusters of acicular crystals, radiating from a common centre.—Selenic acid is very soluble in alcohol; the concentrated solution yields an ether by distillation, and dry selenic acid, coloured red by a portion of the selenium reduced in the operation, remains in the retort.—If sulphuric and selenic acids, and alcohol be distilled together, a large quantity of selenium is reduced, and a volatile substance obtained, of so insupportable an odour, that Berzelius was unable to examine its nature.

If a polished plate of iron or piece of zinc be immersed in a mixed solution of selenic and hydrochloric acids, the metal immediately assumes a copper colour, and the selenium is gradually precipitated in red, brown, or blackish grey flakes, as the temperature is more or less increased. If selenic acid be mixed with sulphuric, the precipitation is less rapid, and the selenium contains sulphur.

The best mode of separating selenium from its solution, is to make the liquid slightly acid, pour in sulphite of ammonia, and boil the mixture for about half an hour, adding from time to time fresh portions of the sulphite. The free acid disengages the sulphurous acid, which then decomposes the selenic.—The liquid first acquires a yellowish colour and becomes turbid; its colour then passes to a fine cinnabar red, and, if heat be not applied, after some hours acid flakes precipitate in large quantity; but the precipitation is not complete unless the solution be boiled; in that case, the precipitate is blackish grey, or almost black. If the liquid contain nitric acid it is better to add hydrochloric acid, and evaporate till the former is decomposed, redissolve in water, and then add the sulphite of ammonia. (Annales de Chimie, Vol. ix. pp. 179 & 229.)

§ 127. *On the Oxygenated Acids lately discovered by Mons. Thenard.*

M. Thenard has announced in the eighth volume of the Annales de Chimie, p. 306, the discovery of some combinations of the nitric and other acids with oxygen, forming a class of highly oxygenated acids, whose existence has not hitherto been suspected. As the facts are altogether new and extraordinary, I shall subjoin the principal characters of these substances, with the modes by which he obtained them, from his communications in the journal above referred to for July and September, 1818.

When barya is heated nearly red for a considerable time in dry oxygen gas over mercury, it absorbs an additional quantity of the gas, and passes to the state of peroxide. It is by means of this substance that the new combinations have been obtained. If the peroxide thus prepared be moistened, it slakes, falls into powder, and its temperature is slightly raised. When diffused through seven or eight times its weight of water, weak nitric acid dissolves it without the disengagement of any gas. The solution, which is perfectly neutral, being freed from the barya by sulphuric acid, oxygenated nitric acid remains combined with the water. This acid is colourless, reddens litmus strongly, and resembles nitric acid in almost all its properties. By heat it gives off oxygen, but is not completely decomposed unless it be boiled for some time. When placed in a vacuum under the receiver of an air pump, by the side of another vessel containing lime, it may be concentrated and an acid obtained, which by distillation affords eleven times its volume of oxygen gas. The oxygenated acid combines readily with barya, potassa, soda, and ammonia, forming neutral salts decomposable by the slightest heat; the oxynitrate of barya loses part of its oxygen at the moment of crystallization, whence it is improbable that these salts can be obtained in regular forms.

The nitrates which result from the decomposition of the oxynitrates, are in the same neutral state as the salt from which they are derived. Oxygenated nitric acid has no action on gold, but readily dissolves those metals which are soluble in common nitric acid. The solution is generally effected without any liberation of gas, and with the production of heat. Sometimes, however, a portion of oxygen is disengaged at the beginning if the action be too strong, as happens when zinc is dissolved in oxygenated nitric acid containing fifteen times its volume of oxygen.

To ascertain the quantity of oxygen contained in the oxygenated nitric acid, peroxide of baryum was first analysed by heating a certain quantity of barya in an excess of oxygen, in a small retort over mercury; it absorbed an additional quantity of oxygen, equally to that it originally contained; hence, the peroxide contains twice as much oxygen as the oxide. In the neutral nitrates the quantity of oxygen in the acid is to that in the base as 5 : 1, consequently, in the neutral oxygenated nitrates, the proportion is as 6 : 1, and in oxygenated nitric acid the volume of azote must be to that of the oxygen as 1 : 3.—(See the Analysis of Nitric Acid, § 135.) The phosphoric, arsenic, and probably boracic acids, may also be similarly oxygenated.

Acetic acid dissolves the peroxide of baryum, almost as readily as nitric acid, without effervescence, and the acid obtained when saturated with potassa and heated gives off a large quantity of oxygen and a portion of carbonic acid; the latter arising from the decompositon of a part of the acid by the action of the oxygen on the application of heat.

By acting on the peroxide of baryum by liquid hydrochloric acid, it was to be expected that water, chlorine, and hydrochlorate of barya would be the result: on the contrary M. Thenard obtained an oxygenated hydrochloric acid.—"This fact," he says, "appeared so extraordinary, that I multiplied my experiments in order to verify it. The following is one of the most decisive. A portion of barya which had absorbed 7.5 cubic inches of oxygen gas to become peroxide, was slaked and dissolved in diluted hydrochloric acid, and the barya precipitated by sulphuric acid. The filtered liquid gave no precipitate either with nitrate of barya or sulphuric acid. It was then saturated with potassa, and heated gradually till it boiled. Almost the exact quantity of oxygen absorbed by the base was collected. Oxygenated hydrochloric acid is a colourles and almost inodorous liquid; it reddens litmus deeply; at a boiling heat it is decomposed, and converted into oxygen and hydrochloric acid; when saturated with potassa, soda, or ammonia, it decomposes much more readily, and oxygen only is disengaged. It dissolves zinc without effervescence; has no immediate action on gold at common temperatures, but its action on oxide of silver is very curious; chloride of silver and water are formed, and the oxygen flies off with an effervescence as lively as if the acid had been poured on a carbonate."

By means of oxygenated hydrochloric acid and oxide of silver, M. Thenard succeeded in combining oxygen with hydrofluoric and sulphuric acids, and indeed all the acids capable of being oxygenated may be obtained in that state by the same means.

Oxygenated hydrofluoric acid retains its oxygen at a boiling heat: sulphuric acid parts with it readily.

Thenard also found that the oxygenated, nitric, and hydrochloric acids may be combined with still further doses of oxygen; it is only necessary to treat them with peroxide of baryum as in the first process: thus, to hyperoxygenise the oxygenated hydrochloric acid, it must be saturated with the peroxide of baryum, the barya separated by sulphuric acid, and the liquid decanted, which will be found to contain all the oxygen of the two portions of the peroxide of baryum employed.

The same acid may even be oxygenated again several times by repetitions of the same process.

When an excess of barya water is added to oxygenated or hyperoxygenated nitric or hydrochloric acid, an abundant crystalline precipitate of hydrate of peroxide of baryum is formed in small plates of a pearly lustre sparingly soluble in water, which at 50° Faht. decomposes them into oxygen gas and barya. Both strontia and lime are capable of becoming peroxides, like barya, by the action of the hyperoxygenated acid: the hydrate of peroxide of strontium is very like that of baryum; that of lime is in smaller plates. Such are the facts contained in M. Thenard's first communication: it was read at the sitting of the Académie des Sciences, on the 27th of July, 1818.—(See Annales de Chimie, vol. viii. p. 306.)

I proceed to the second communication, read on the 14th of September following, to the same learned Society.

M. Thenard's first object was to determine the maximum of oxygen that can be combined with hydrochloric acid. By repeating the process with perchloride of baryum, already detailed, fifteen times, he obtained an acid, containing at the temperature of 68° and under a pressure of 29.92 inches of mercury, 7 volumes of oxygen to 1 of hydrochloric acid gas.

During the first five or six times that the process was repeated no oxygen gas was disengaged, but beyond that it became difficult to prevent the escape of a small portion; the greater part however always remained combined with the acid. The hydrochloric acid employed was in such a state of concentration, that when saturated with barya and slightly evaporated, crystals of hydrochlorate of barya were deposited from the solution.

This oxygenated acid is still capable of combining with more oxygen by the action of sulphate of silver; an insoluble chloride, and a very soluble oxygenated sulphuric acid are immediately formed. The chloride being separated by the filter, hydrochloric acid, in less quantity than was contained in the oxygenated hydrochloric acid employed, was added to the oxygenated sulphuric acid, and a portion of barya water dropped in just sufficient to precipitate the sulphuric acid. The liberated oxygen is thus transferred to the hydrochloric acid, which passes at once to its maximum of oxygenation. In this manner Thenard obtained an acid, containing nearly 16 volumes of oxygen to 1 of real hydrochloric acid.

This acid, recently prepared, did not disengage any gas on being filtered; but soon after, small bubbles rose from the bottom of the vessel and burst at the surface of the liquid. Thinking this might arise from the action of light, Thenard filled a small phial nearly to the top with the acid, put in the stopper, and left it inverted, in the dark. After some hours it exploded; the acid contained more than 30 volumes of oxygen; yet the same acid under an exhausted receiver gave off only a very small portion of gas that had been mechanically retained by it.

The whole of the oxygen is not expelled from oxygenated hydrochloric acid even by boiling, for on bringing it in contact with oxide of silver oxygen gas is immediately set free. By means of this oxide, it is easy to determine the quantity of oxygen contained in the oxygenated hydrochloric acid. Pour mercury into a graduated glass tube to within a few divisions of the top, and fill it up with the acid, invert the tube over mercury, and pass up an excess of oxide of silver suspended in water. The oxygen is immediately disengaged, and its quantity may be read off on the divisions of the tube. The quantity of chlorine and consequently that of the hydrochloric acid must be ascertained by a separate experiment, with another portion of the acid and nitrate of silver; 100 parts of chloride of silver, indicate 24.5 of chlorine, or 25.27 of hydrochloric acid (*a*). The disengagement of the oxygen is so sudden that there is some danger in operating on a weak acid, containing from 26 to 30 volumes of oxygen.

Hydrochloric acid at its maximum of oxidation occasions no effervescence when poured on sulphate, nitrate, or fluate of silver; the oxygen is transferred to the acid of the salt, and chloride of silver and water are formed.

The oxides of zinc, copper, and nickel may be hyperoxidated by dissolving them in hydrochloric acid three or four times oxygenated, and decomposing the metallic salts by potassa or soda in very slight excess; the oxides precipitate in the state of oxygenated hydrates; that of zinc is yellowish, copper olive green, and nickel light dirty apple green. They are decomposed by a heat below that of boiling water.

Another paper was read by M. Thenard on the 5th of October, 1818.

(*a*) Having observed lately that a portion of the oxygen of the oxide of silver is disengaged in this experiment, account must be taken of the quantity liberated, that the analysis may be correct (note by M. Thenard). This is done by a separate experiment, in which the chloride of silver, mixed with the excess of oxide is collected and treated with ammonia; the metal of the reduced oxide will be left undissolved, from the quantity of which that of the oxygen sought is obtained; 100 parts of oxide of silver contain 7 parts of oxygen.

The subject of this communication is principally the singular results which are obtained by the action of the oxygenated acids, on certain metallic oxides.

Hydrate of deutoxide of mercury is dissolved by oxygenated nitric and hydrochloric acids without effervescence, but on adding an excess of alkali, the oxide is quickly reduced. The hydrate is also reduced by the neutral oxygenated nitrates and hydrochlorates of potassa.

Oxide of gold precipitated by barya, placed whilst wet in contact with oxygenated hydrochloric acid, produced a brisk effervescence, became purple, and was reduced. Oxygenated sulphuric, nitric, and phosphoric acids at first changed oxide of gold purple; it then became deep brown. When oxygenated nitric acid is poured on oxide of silver, a brisk effervescence ensues from the escape of oxygen gas, one part of the oxide is dissolved, the other is first reduced, and, if the acid be in sufficient quantity, afterwards dissolved. If potassa be added to the solution a fresh effervescence takes place, and a dark violet coloured precipitate, insoluble in ammonia falls down.

If very fine silver filings be put into a solution of oxygenated nitrate or hydrochlorate of potassa, all the oxygen of the salt is instantly disengaged, but the silver is not acted on, and the salt remains neutral as before.

Iron, copper, zinc, bismuth, lead and platina produce the same effect. The zinc and iron become oxidated in the process. Gold and tin produce no effect.

Oxygenated nitric acid readily dissolves the peroxides of manganese and lead; the solution is attended with the evolution of much oxygen gas. Potassa precipitates the manganese in black flakes, and the lead of a brick red colour.

M. Thenard thinks these phenomena may probably be ascribed to electrical energies; be their cause what it may, they are curious, and if future experiments shall confirm his statements, will introduce a new set of bodies which cannot fail to attract the attention of chemists, and may perhaps lead to new views of a very important class of substances. I trust I shall therefore be pardoned for having gone somewhat out of my way in laying the subject so fully before the reader, especially as it is not yet noticed in any of our systems of chemistry. I shall not stop to enquire whether these substances are really new chemical compounds, or only acid solutions holding oxygen in mechanical combination, as air is held in water. The fact stated at page 159, that the hyperoxygenated hydrochloric acid, containing more than thirty times its volume of oxygen, did not part with it, on the removal of atmospheric pressure, is adverse to the latter supposition.

The whole of the preceding account is taken from the papers by M. Thenard, in the Annales de Chimie, already mentioned.

The following observations on the influence of water in the formation of the oxygenated acids, have appeared since the preceding section was written. They are too intimately connected with the subject, not to be briefly noticed in this place.

The experiments detailed above, have shewn that oxide of silver decomposes oxygenated hydrochloric acid, and immediately expels all the oxygen; but if a salt of silver, as the sulphate or nitrate, &c. be employed, the oxygen remains in the liquid. The inference from this seems to be that by the intervention of water, oxygen can unite to acids, but that it cannot unite to water alone; for if it could, why is it expelled in the first experiment? But, since silver and other substances produce chemical changes on oxygenated hydrochlorate, &c. of potassa, by purely physical action, the deduction is incorrect, and it remains to be proved, if water alone be not capable of oxygenation.

Barya water was dropped by degrees into a solution of oxygenated sulphuric acid, and the liquid shaken after each addition. No effervescence took place, till the acid was nearly saturated, when it became pretty brisk and sulphate of barya precipitated in flakes. The neutralization was then completed as speedily as possible, and the liquid filtered; it gave no precipitate with nitrate of barya, or sulphuric acid, but it nevertheless contained much oxygen: it left scarcely any residuum when evaporated to dryness. Hence it appears that water may be oxygenated, and Thenard adds, he finds that it is capable of taking up more than six times its volume.

Oxygenated water does not give up its oxygen by being placed in a vacuum; it becomes concentrated, and at last evaporates. It freezes also without undergoing any change, but boiling deprives it of all its oxygen. It immediately reduces oxide of silver, and is at the same time deoxygenated with great effervescence. Silver and the puce coloured oxide of lead also deprive it of its oxygen. Water of barya, strontia, and lime, form a multitude of small spangle-form crystals, similar to those which are produced by mixing an oxygenated acid with the same alkaline solutions.

Pure oxygenated water gives up its oxygen much more readily, than when combined with an acid. Heat a portion of it till it gives off oxygen abundantly, then drop in a little hot sulphuric, or nitric, acid; the effervescence will cease immediately. The oxygenated acids may even be heated for more than an hour, without parting with nearly all their oxygen, except the fluoric, which, if the experiment be made in a glass vessel, gives it off rather sooner than the others, in consequence of its action on the glass. Sugar and many other vegetable and animal substances, and probably almost all bodies, either promote or weaken the union of oxygen with water. All the acids tend to produce the first effect; the metals, their sulphurets, and oxides, carbon, &c. the second; "which," M. Thenard adds "tends to shew us more and more that these are electrical phenomena." (An. de Chimie. vol. IX. p. 314.)

Analysis of Mineral Acids.

§ 128. No general rule can be given for the analysis of these substances; it will be necessary to consider each separately. They are the boracic, carbonic, chlorocarbonic, phosphoric, phosphorous, hypophosphorous, nitric, nitrous, pernitrous (the existence of the last is problematical) sulphuric, sulphurous, chloric, perchloric, iodic, chloriodic, selenic, hydrofluoric, hydrosulphuric, (sulphuretted hydrogen) hydriodic, hydrochloric, fluosilicic, fluoboric, arsenic, chromic, molybdic, columbic, and tungstic.

The five last are metallic oxides, and to them M. Thenard doubts whether we ought not to add the deutoxide of arsenic, the deutoxide and tritoxide of antimony, and the oxide of tellurium, as, with the exception of the last, Dr. Thomson has done; and that he says "might be called telluric acid, but as it likewise possesses alkaline properties, it will be better to retain the common name oxide of tellurium." Of the propriety of considering the deutoxide of arsenic, and the deutoxide and tritoxide of antimony as acids there can be no doubt, since they possess not only the property of forming neutral salts with various bases, but also that of reddening vegetable blues, which the others are deficient in. Whether it be equally correct to consider the neutralizing power alone a just title to the rank of an acid, is matter of dispute. Dr. Thomson follows Smithson in the affirmative, who suggested that silica, which exists in various neutral stony bodies in combination with earths and metallic oxides, "performs in them the functions of an acid," and adds "that this has been demonstrated in a satisfactory manner by Berzelius." Be that as it may, I have taken the liberty of deviating both from my author and Dr. Thomson, by adding to the list of mineral acids, the arsenious, antimonious, and antimonic only, which thus makes the whole number of those bodies thirty. I have already given my reasons for excluding the hypothetical phosphatic acid of M. Dulong.

§ 129. *Boracic Acid.*—No very satisfactory results have hitherto been obtained, in the attempts to analyse this substance: its base, when heated to nearly 600° in oxygen gas, takes fire and burns with great brilliancy, absorbs oxygen and becomes partly converted into boracic acid, which fuses, forms a coat over the remaining boron and puts an end to the combustion. When this is washed off, and the boron again heated more strongly than before, it burns afresh, and by repeating these operations, the whole may be converted into boracic acid. In this way Davy found boracic acid to consist of about one part of boron and one and three quarters of oxygen. Gay Lussac and Thenard acidified a portion by heating it in nitric acid, and they conclude from the experiment that boron unites with half its weight of oxygen to become boracic acid.

Davy attempted to decompose boracic acid by potassium. The result gave the composition of boracic acid, as boron 1, oxygen 2.52. Berzelius ascertained that 100 parts of borate of ammonia, contain 44.41 of ammonia. The equivalent for ammonia, hydrogen being considered as unity, is 16, and since one atom of ammonia unites with one atom of acid to form a neutral compound, the weight of an atom of boracic acid must be about 20. On the idea that boracic acid is composed of 2 atoms of oxygen and 1 of boron, the weight of an atom of the latter must be 5, for that of oxygen is 7.5.

§ 130. *Carbonic Acid.*—This gaseous acid is partly decomposed, by passing electric sparks through it for a considerable length of time; the gas increases in bulk, the wires become oxidated, and carbonic oxide is evolved.

Hydrogen and carbon decompose carbonic acid; the products in the first case are water and carbonic oxide, in the second, carbonic oxide only. The first experiment is performed by slowly passing a mixture of equal parts by bulk of carbonic acid and hydrogen gases, through a porcelain tube heated to redness. The gases may be contained in a bladder connected with the porcelain tube, traversing a small furnace, to the opposite end of which a bent glass tube is fixed which passes into a receiver full of and inverted over mercury. Water will soon be seen trickling down the sides of the receiver, and carbonic oxide will pass into it.

To effect the decomposition of carbonic acid by charcoal, fill the middle of the porcelain tube, of the last experiment, with fragments of fresh well burnt and quite dry charcoal, and connect it with two bladders, or mercurial gasometers, one empty, the other filled with the gaseous acid; heat the tube to whiteness, and pass the gas backwards and forwards, five or six times over the charcoal, from one vessel to the other: the volume of gas will be doubled, and it will be wholly converted into carbonic oxide.

Tennant (a) and Pearson have shewn that carbonic acid when united to a base, as in marble, is decomposed at a high temperature by phosphorus.

Potassium and sodium also decompose carbonic acid, but there must be an excess of metal, that the decomposition may be complete; otherwise, a part of the acid will be absorbed. The experiment is made by filling a small bent glass tube with mercury, passing up first a portion of carbonic acid gas into it, and then the potassium, and heating the whole strongly with a spirit lamp. The metal gradually loses its

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(a) This gentleman was one of the first to prove the identity of diamond and charcoal, by converting the former wholly into carbonic acid, by combustion with nitre. He mixed 2.5 grains of diamond with 120 of nitre and kept the mixture at a red heat for half an hour. The diamond was consumed by the oxygen evolved by the nitre.

Mr. Tennant lost his life in the year 1814, by a deplorable accident in endeavouring to pass an ill-secured drawbridge, leading to a fort on a hill near Boulogne, soon after he had been elected professor of chemistry in the University of Cambridge: in him, science will long mourn the loss of one of her ablest votaries, society an ornament, humanity a friend.

brilliancy, when it is to be stirred with an iron wire; it then becomes pasty, and in a short time the gas is decomposed. The carbon is easily separated at the end of the process, being the only product insoluble in water.

Iron and zinc, and probably other metals of the third division, also decompose carbonic acid, at high temperatures; the metal is oxidated and carbonic oxide evolved.

The proportions of the elements of carbonic acid are shewn by burning charcoal in excess, in perfectly pure and dry oxygen gas over mercury; the whole of the gas will be converted into carbonic acid, and its volume remain unaltered. The specific gravity of carbonic acid is 1.523, and that of oxygen 1.106, consequently carbonic acid is composed of 27.38 of carbon and 72.62 of oxygen, or of one volume of vapour of carbon and one volume of oxygen condensed into one.

§ 131. *Chlorocarbonic Acid Gas.*—Heat a portion of tin or zinc in the gas, in a small retort over mercury, by a spirit lamp; a metallic chloride will be formed, and a volume of carbonic oxide, equal to that of the chlorocarbonic acid gas employed, evolved. A comparison of the specific gravities will shew the proportions in which the elements of this gas are combined.

Specific gravity of chlorine . .	2.4713
——————Oxide of carbon	0.9737
Chlorocarbonic acid	3.4450

Hence it is evident that chlorocarbonic acid gas, consists of one volume of chlorine and one of carbonic oxide, condensed into one volume, or of one volume of chlorine, one of vapour of carbon, and half a volume of oxygen.

§ 132. *Phosphoric Acid.*—Chemists have been extremely divided on the composition of this acid; many eminent men have devoted their attention to the subject, and scarcely any two have obtained corresponding results.

In most chemical works it is stated that the composition of this acid is easily found by burning phosphorus in oxygen gas: but the object is not accomplished with the facility that might be expected, for in the common method the phosphorus is extinguished by the phosphoric acid formed, and the process consequently terminated, before the whole of the phosphorus is consumed; which renders it difficult to determine precisely the quantity burnt. Thomson and Berzelius adopted another method, and ascertained the composition of phosphoric acid, from that of the neutral phosphates, the proportion of oxygen in the bases of which, being known, that in the acid was inferred according to the law mentioned in a preceding section (§ 102) (*a*).

(*a*) In the course of his experiments, Berzelius found great discrepancies in the results of his analyses of phosphate of lead; wishing to obtain an acid phosphate of lead, he poured phosphoric acid into a solution of nitrate of lead. At first no precipitate ensued; but after some hours the glass was covered with very small transparent crystals, insoluble in water; these, being heated in a retort, decrepitated and gave off water, and by a stronger heat, a quantity of red fumes of nitrous vapour was disengaged; 10 parts of the salts well dried gave 8.827 of phosphate of lead. It was composed therefore of phosphate and nitrate of lead and the proportions varied, according as the nitrate of lead had been employed in greater or less excess.

This tendency of phosphoric acid to form double salts with nitric acid, is not confined to its combination with oxide of lead; Berzelius

Sir Humphry Davy has more lately pointed out a method of effecting the combustion of phosphorus in oxygen, not liable to the objection stated above. It consists in inclosing the phosphorus in a small curved tube, whose neck is drawn out so as to leave an aperture of about one-tenth of an inch. This is previously accurately weighed and placed in a retort, which is then exhausted, and connected with a graduated jar of oxygen gas over mercury, so that a constant supply can be kept up in proportion as the gas is consumed, and the quantity absorbed easily ascertained. The heat of a spirit lamp, applied to the bottom of the retort, volatilizes the phosphorus, which burns in the state of vapour as it issues from the aperture of the curved tube (see the figure.). In this way, Davy found, taking the mean of three experiments, that 7.8 grains of phosphorus, absorb 30.91 cubic inches of oxygen, which supposing 100 cubic inches to weigh 33.9 grains (barometer 29.8, thermometer between 46° and 49° Fahrenheit) gives the composition of phosphoric acid,

Phosphorus	100
Oxygen	134.5

(Phil. Trans. 1818.)

§ 133. *Phosphorous Acid.*—If chloride of phosphorus, obtained by passing the vapour of phosphorus over corrosive sublimate heated in a glass or porcelain tube, be acted on by water, both fluids are decomposed, the chlorine of the chloride unites with the hydrogen

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found that it is the same with barya. It is important to those who engage in the analysis of substances containing phosphoric acid, to keep these facts in their recollection. (Ann. de Chimie, vol. II. p. 158.)

of the water, to form hydrochloric acid, and its oxygen combining with the phosphorus forms phosphorous acid.—As these combinations are definite, if we ascertain the quantity of any one of the elements, that of the rest is easily found by calculation. All that is necessary therefore for the analysis of phosphorous acid, is to separate the chlorine of the hydrochloric acid by means of nitrate of silver, from the quantity of which we arrive at that of the oxygen in the phosphorous acid; but since phosphorous acid, especially if concentrated, precipitates nitrate of silver, it is necessary to guard against error from this cause, which is easily done by washing the chloride of silver with diluted nitric acid, which will dissolve the phosphite of silver, but not touch the chloride.

Sir Humphry Davy made the following experiment. —32.7 grains of the fluid chloride of phosphorus were acted on by water and precipitated by nitrate of silver. The chloride of silver, when dried and fused, weighed 98.4 grains, which, allowing 24.5 per cent. of chlorine in horn silver, gives the composition of the chloride of phosphorus,

Chlorine . . .	24.108
Phosphorus . .	8.592
	32.7

33.5 of chlorine require one of hydrogen to form hydrochloric acid, and 1 of hydrogen requires 7.5 of oxygen to form water. Therefore the 24.108 have taken 0.719 of hydrogen, and set free 5.4125 of oxygen, which have combined with the 8.592 of phosphorus. According to this experiment, phosphorous acid is composed of

Phosphorus . . .	100
Oxygen	63

§ 134. *Hypophosphorous Acid.*—Neutral hypophosphite of barya, when heated out of contact with the air, is converted into gaseous hydruret of phosphorus, and acid phosphate of barya. These results are the consequence of the decomposition of the water contained in the salt; and, as in the last case, the new compounds being definite, if the proportions of their elements be known, we may easily deduce those of the hypophosphorous acid. For if the portion of phosphorus contained in the hydruret be added to the phosphoric acid, and the portion of oxygen which was derived from the water, be subtracted from it, the remainder must be the hypophosphorous acid. The composition of phosphoric acid is known already, we have therefore to find that of the acid phosphate of barya, and the hydruret of phosphorus.

Sir Humphry Davy found 29 grains of hypophosphite of barya lost 3.5 grains on being heated, which were gaseous hydruret of phosphorus, and consisted of hydrogen 0.525, phosphorus 2.975. The remaining acid phosphate contained barya 14.47, phosphoric acid 11.03, and since phosphoric acid contains one atom of phosphorus 11.25, and 2 of oxygen 15, the 11.03 are formed of phosphorus 4.72 + oxygen 6.31. Therefore, to find the composition of hypophosphorous acid, 4.72 + 2.975 = 7.695, the quantity of phosphorus, and 6.31 — 3.93 (the quantity of oxygen required by 0.525 of hydrogen to form water) = 2.38, which denotes the oxygen. Hypophosphorous acid therefore consists of

Phosphorus . . .	100
Oxygen	30.93
	130.93

§ 135. *Nitric Acid.*—Azote, chlorine, and iodine have no action on nitric acid, but it is decomposed by all the simple combustibles, except diamond, gold, platina, rhodium and columbium. The proportions of its elements, however, cannot be ascertained by this method, but may be learnt by passing up successively 133 measures of deutoxide of azote and 150 of oxygen into a tube between three and four tenths of an inch in diameter, full of water. The tube is to be left at rest some minutes, when about 233 parts will be absorbed, and a solution of pure nitric acid, with a residuum of 50 measures of oxygen obtained. If the deutoxide of azote be in larger proportion to the oxygen, the acid will not be pure, but more or less nitrous acid will be formed, and may be detected by its discolouring the red sulphate of manganese, as M. Gay Lussac has observed. Deutoxide of azote is composed of equal volumes of oxygen gas and azote; whence it follows that nitric acid contains one volume of azote, and two volumes and a half of oxygen, or by weight 35.12 azote, and 100 oxygen.

§ 136. *Nitrous Acid.*—M. Dulong analysed this acid, by passing it through very fine red hot iron or copper wire in a porcelain tube, with one end of which a retort containing the acid was connected, with the other, a glass tube filled with chloride of calcium, and to that another small bent tube leading under the receiver in which the gas was collected.

As soon as the porcelain tube was red hot, heat was applied to the retort, and the acid reduced by degrees to vapour. Its oxygen united with the metal, and the disengaged azote passed into the receiver, depositing any water it might contain, on the chloride of calcium, in its passage through it.

The increased weight of the metal, that of the tube with the chloride of calcium, and the volume of the gas, gave the proportion of azote and oxygen in the nitrous acid. The following were the results of the experiment. Ther. 60° Faht.

		Grs.
The acid weighed		122.54
Increased weight of the metal . . .	87.39	
ditto of the chlorine . .	0.26	
The volume of dry gas evolved was 126.32 cubic inches, but it contained 4.06 cub. in. of hydrogen, indicating .68 of a gr. of oxygen, and the .26 of water indicate .22, together	0.90	
Hence the oxygen from the acid (87.39—0.90) was	86.49	
Azote (126.32—4.06=122.26) . .	36.18	
		122.67

Or oxygen 100, azote 41.83—

	Cub. In.
And by volume, oxygen	250.35
——— azote	122.26

These results very nearly agree with those obtained by Gay Lussac, who found that 200 volumes of deutoxide of azote, combine with 100 of oxygen, to form nitrous acid; according to which, it is composed of two volumes of oxygen and one of azote, or by weight of 100 oxygen and 43.85 of azote.

§ 137. *Pernitrous Acid.*—It has been stated in a preceding page, that this acid cannot be obtained insulated, its composition therefore must be ascertained, either synthetically, or by the decomposition of a pernitrite. The former method is the most accurate. Pass into a tube over mercury, 500 or 600 parts of deutoxide of azote, 100 parts of oxygen, and a little alkaline solution, an absorption amounting to 500 parts will ensue, consisting of 400 deutoxide, and 100 oxygen. Now 400 deutoxide contain 200 azote and 200 oxygen, consequently the new acid is composed of three parts oxygen and two of azote, or of 150 of the former, and 100 of the latter. I have already said the existence of this acid is questionable.

§ 138. *Sulphuric Acid.*—The composition of this acid may be ascertained by passing it through a porcelain tube, heated nearly to whiteness, whose diameter must not much exceed two-tenths of an inch. The apparatus, and mode of making the experiment, are similar to that for decomposing nitrous acid, except that the tube with the chloride of calcium, and the metallic wire is omitted. As soon as the decomposition begins, abundance of vapours appear in the bent glass tube, and a large quantity of cloudy gas collects in the receiver over the mercury. Let a portion of this gas be agitated in a tube over water; two-thirds will be absorbed, which are sulphurous acid, and one-third of oxygen will remain. Sulphuric acid therefore consists of sulphurous acid plus half its bulk of oxygen, and the proportions of its elements will be demonstrated, when we have found the composition of the latter acid.

§ 139. *Sulphurous Acid.*—If sulphur be burnt in oxygen gas, a volume of sulphurous acid gas, within a few hundredth parts equal to that of the oxygen, is obtained. As sulphur always contains hydrogen, the deficiency is easily accounted for, and there can be little doubt, that sulphurous acid consists of a volume of the vapour of sulphur, and a volume of oxygen, condensed into one volume. The specific gravity of sulphurous acid gas is 2.213, and that of oxygen 1.106 the difference, or 1.107 must be the weight of the sulphur.

According to this experiment then, sulphurous acid consists of 100 sulphur and 100 oxygen, and sulphuric acid of 100 sulphur and 150 oxygen.

" There is another experiment which demonstrates in a very satisfactory manner the composition of sulphurous acid. Sulphuretted hydrogen consists of hydrogen holding a quantity of sulphur in solution. Now one volume of this gas requires one volume and a half of oxygen for its compleat combustion. The substances formed, are water and sulphurous acid. The half volume of the oxygen goes to the formation of water, and combines with the hydrogen. The one volume of oxygen combines with all the sulphur, and forms sulphurous acid. The sulphur in a volume of sulphuretted hydrogen is obtained by subtracting the specific gravity of hydrogen gas, from that of sulphuretted hydrogen.

Specific gravity of sulphuretted hydrogen . .	1.180
——————— hydrogen gas	0.069
Sulphur in the gas	1.111

" But the specific gravity of oxygen gas is 1.111. Hence it follows that sulphuric acid is composed of

Sulphur	1.111
Oxygen	1.111

(Thomson's Chemistry, Vol. I. p. 280. 5th edit.)

§ 140. *Iodic Acid.*—100 parts of dry iodate of potassa, decomposed by heat, yield 22.59 of oxygen, and 77.41 of iodide of potassium, containing 58.937 of iodine, and 18.473 of potassium; now these absorb 3.773 of oxygen to become potassa, there remain therefore 18.817 parts to acidify the 58.937 of iodine; consequently iodic acid is composed by weight of 100 iodine + 31.928 oxygen; or of one volume of the vapour of iodine, and two volumes and a half of oxygen. (Gay Lussac.)

§ 141. *Chloric Acid.*—If 100 parts of well dried chloride of potassa be decomposed by heat in a glass retort, we obtain 38.88 parts of oxygen, and 61.12 of chloride of potassium, which contain 32.196 of potassium, and 28.924 of chlorine; but 32.196 of potassium absorb 6.576 of oxygen to become potassa; there remain therefore (38.88—6.576) 32.304 parts of oxygen, to convert 28.924 of chlorine into chloric acid; consequently it is composed by weight of 100 chlorine + 111.68 oxygen—or of one volume of chlorine, and two volumes and a half of oxygen. (Gay Lussac.)

§ 142. *Perchloric Acid.*—The analysis of this acid, like that of the preceding, is to be effected by the decomposition of the neutral salt, formed by its combination with potassa. For more particular details see section 122.

§ 143. *Chloriodic Acid.*—The analysis of this acid is a problem of considerable difficulty, which has not yet been satisfactorily solved, arising in great measure from the tendency of the acid to combine with additional portions of iodine, whence it is not easy to ascertain the exact point of saturation of the two substances. Sir Humphry Davy made two experiments to determine its composition, by admitting chlorine in excess, to known quantities of iodine in vessels exhausted of air, and repeatedly heating the sublimate. In the first experiment, in which the sublimate was dissolved by admitting a small quantity of water into the retort, eight grains of iodine absorbed 5.25 cubic inches of chlorine. In the second, in which the sublimate was not dissolved, but the absorption estimated by the admission of fresh quantities of the gas, 20 grains absorbed 9.6 cubic inches of chlorine. Taking the quantity of iodine in each experiment at 20 grs. the weight of chlorine absorbed is,

In the first . .	9.99 grs.
In the second .	7.32
The mean of the two .	8.65

Gay Lussac determined the composition of hydriodic acid to be,

Iodine	100.
Hydrogen . . .	0.849

which, considering hydrogen as unity, gives as the equivalent for iodine 117.77, or omitting fractions 117.

Now 20 : 8.65 : : 117 : 50.1, but the equivalent for chlorine is 33.5. According to this, chloriodic acid is composed of two atoms of iodine and three of chlorine. But as Sir Humphry Davy has observed, "the estimation of its composition from experiments on the quantity of chlorine absorbed in close vessels, must necessarily be liable to error."—(Phil. Trans. 1814; p. 498.)

§ 144. *Selenic Acid.*—Berzelius, finding it impossible to obtain correct results as to the composition of selenic acid, by directly combining selenium with oxygen, had recourse to the action of chlorine. For this purpose he heated selenium in chlorine. It became hot, liquified, and formed at first a brown fluid: when saturated with chlorine, it afforded a white solid mass of chloride of selenium, which sublimed by heat in the form of a yellow vapour, like selenic acid, and condensed again in small white crystals. By continuing the sublimation, a compact white mass was obtained, which dissolved in water with disengagement of heat, and gave a very acid colourless solution. Selenium appears capable of combining in more than one proportion with chlorine; the chloride is a brownish yellow transparent substance, with an oily appearance, requiring a higher temperature to volatilize it, than the perchloride. It is decomposed by water into selenic and hydrochloric acids. Berzelius found the perchloride of selenium to consist of

Selenium	1.
Chlorine . . .	1.79
	2.79

According to this result, supposing the perchloride to contain two atoms of chlorine, the equivalent number for selenium is 37.43, hydrogen being unity, and chlorine 33.5. The experiment was made by passing dry chlorine into a tube containing a gramme (15.444 grs.) of selenium, 'till the latter was perfectly saturated with the gas; the excess of which was then displaced by atmospheric air, and the increase of weight ascertained. Calculating from these data, selenic acid must consist of

Selenium . . .	37.43	or	100
Oxygen . . .	15.00		40

For the equivalent for oxygen is 7.5; and 33.5: 7.5:: 1.79: 4; and 1: 4:: 37.43: 14.97. Consequently selenic acid consists of one proportion of selenium and two of oxygen.—(Annales de Chimie, vol. ix. p. 226.)

§ 145. *Chromic Acid* has not been hitherto analysed, and the operation is one of considerable difficulty, from our ignorance of any means by which a sufficient quantity of chromium may be obtained in its pure metallic state; but it is easy to ascertain how much oxygen the oxide of chromium requires to become chromic acid, by calcining chromate of mercury in a porcelain retort, which thus is decomposed into mercury, oxide of chromium and oxygen. The weight of the first gives that of the oxygen combined with it in the state of oxide, and the difference between that and the whole weight of oxygen, gives the portion derived from the chromic acid.

From his experiments on the chromates of lead and barya, Berzelius conceives that chromic acid contains twice as much oxygen as the green oxide of chromium.

According to him the green oxide consists of

	Chromium	100.
	Oxygen	43.86
And chromic acid of	Chromium . . .	100.
	Oxygen	87.72

§ 146. *Molybdic Acid.*—Bucholz formed molybdic acid by submitting molybdena in fine powder to the action of nitric acid: according to his experiments, molybdic acid contains

Molybdena	100.
Oxygen	49.92

§ 147. *Columbic Acid.*—We know no means by which the composition of this acid may be correctly ascertained.

§ 148. *Tungstic Acid.*—We have no direct analysis of this acid that can be depended on: Berzelius found the sulphuret of tungsten to be composed of

Tungsten . . .	75.04
Sulphur	24.96,

and that when a hundred parts of this sulphuret were burnt on a platina tray, till the disengagement of sulphurous acid gas ceased, they left a residuum of 93.5 parts of tungstic acid; consequently 24.96 of sulphur are replaced by 18.46 of oxygen, and hence 100 parts of tungsten combine with 24.6 of oxygen to form tungstic acid;—for 93.5—75.04 = 18.46, and 75.04 : 18.46 : : 100 : 24.6.—(Thomson's Annals, Vol. iii. p. 244.)

§ 149. *Antimonious Acid.*—On 100 parts of perfectly pure and pulverized antimony, in a platina crucible previously weighed, pour first diluted nitric acid, and submit it to a gentle heat: it will thus be converted into an insoluble subnitrate. Then pour off the clear liquid, and add strong nitric acid; evaporate the whole to dryness, and calcine the residual mass at a red heat. By the action of the second acid, the metal will be further oxidated and pass to a yellow colour; by calcination it becomes white, and, according to Thenard, acquires an increase of weight equal to 26.07, which is oxygen.

§ 150. *Antimonic Acid.*—When submitted to a very high heat it abandons a portion of its oxygen, and is converted into antimonious acid. We have no good analysis of it, but Berzelius supposes it from analogy to contain twice as much oxygen as the protoxide, which he states to be composed of 100 metal + 18.6 oxygen, and consequently that it is formed of antimony 100, + oxygen 37.2.

§ 151. *Arsenic* and *Arsenious Acids.* Convert a certain quantity of the white arsenic of the shops into arsenic acid, by boiling it with six parts of aqua regia, (composed of four parts nitric and two of hydrochloric acid) in a glass retort, to which a receiver is adapted, till it becomes syrupy; then pour it into a porcelain basin and evaporate it gently to dryness. Weigh off a portion of the dry acid, redissolve it in distilled water, and saturate the solution with hydrate of potassa, and pour into it a solution of nitrate of lead; all the arsenic acid will fall down, combined with the lead, in the state of arseniate, which may be collected on a filter, well washed and weighed.

To know how much oxygen is contained in the arsenic acid, it is only necessary to know the quantity of acid in the arseniate of lead, which is found by dissolving a certain quantity of lead in nitric acid, adding to the neutral solution a neutral solution of arseniate of potassa, weighing the precipitated arseniate, and remembering that 100 parts of lead absorb 7.7 to become protoxide. Suppose 100 parts of arsenic afford 511.09 parts of arseniate of lead, and that 333.95 parts of lead, give the same quantity of arseniate; then the arsenic acid will be composed of 100 arsenic, and 51.428 of oxygen; for the 511.09 of arseniate consists of 333.95 of lead, 100 of arsenic, and 77.14 oxygen; of which 25.72 parts are combined with the lead, and consequently 51.42 parts with the arsenic. More lately M. Berzelius has announced that these results are incorrect, and that none of the analyses hitherto published have given the true composition of the acids of arsenic. According to him arsenious acid is composed of 100 arsenic, and 31.77 of oxygen, and arsenic acid, of 100 arsenic, and 52.96 of oxygen, the quantity of oxygen in the former being to that in the latter as 3 to 5. 100 parts of white arsenic, decomposed by sulphuretted, hydrogen, give 124.5 parts of sulphuret of arsenic, and 100 parts of white arsenic decomposed by sulphur in a weighed apparatus lose 48.4 parts, in sulphurous acid, which flies off. (An. de Chimie, t. v. p. 179.) For every atom of sulphur, which in the first of these two experiments combines with the arsenic, an atom of oxygen must have been carried off by the hydrogen, and its quantity is denoted by the increase of weight acquired by the sulphuret: now, an atom of sulphur is just double the weight of an atom of oxygen; consequently, the 100 parts of white arsenic (arsenious acid) contain 24.6 parts of oxygen. Again, since sulphurous acid contains half its weight of oxygen $\frac{48.4}{2} = 24.2$ indicate the quantity of oxygen in 100 parts of arsenious acid, according to the second experiment.

§ 152. *Hydrofluoric Acid.*—As in all cases when direct evidence cannot be adduced, presumptive must be had recourse to, so in the present we are led by the presumption of strong analogy to consider this acid as composed of hydrogen and a certain base, although that base neither has been, nor probably ever will be obtained in an insulated state. This arises from the intense affinities which it exerts, so that it can no sooner be separated from one body, than it combines with another. Hydrofluoric acid is a colourless liquid, like water, which remains fluid when cooled to 4° Faht. and boils at a low, but not ascertained temperature. Its specific gravity, according to Davy, is 1.0609. When exposed to the air it gives off very abundant dense white fumes, of an intolerably suffocating and highly corrosive nature, and if a drop of it touch the skin it instantly destroys its texture and produces a painful sore. When a drop of water falls into this acid a hissing noise is heard, and if several drops be added the liquid begins to boil. The action of potassium on this acid is very violent, a solid white substance is formed, and hydrogen gas disengaged.—When fluoric acid is submitted to a current of electricity by the voltaic apparatus, hydrogen is evolved at the negative platina wire, and the positive is covered with a chocolate coloured substance. Now, on the supposition that this acid contains no water, these phenomena can only be explained by the hypothesis that it consists of a peculiar base (fluorine) and hydrogen; and, as all attempts to discover water in it have failed, we can hardly refuse our assent to its probability, even if we withhold our absolute conviction.

The proportion of the elements of hydrofluoric acid have not been correctly ascertained; but, from the composition of fluor spar, which may be considered as a fluoride of calcium, and supposing the acid to be formed of equal volumes of hydrogen and fluorine, the weight of the former to that of the latter must be about 1 to 15.—(See Davy's interesting paper on this subject, Phil. Trans. 1813 and 1814.)

§ 153. *Sulphuretted Hydrogen* may be examined by keeping tin melted in a portion of the gas, by a spirit lamp, in a small retort over mercury, for about half an hour; sulphuret of tin is formed, and a volume of pure hydrogen remains, which, when the apparatus is cool, will be found exactly equal to the volume of the gas.

When electrical sparks are passed for a long time through sulphuretted hydrogen, sulphur only is deposited, and pure hydrogen remains; and if sulphur be heated strongly in hydrogen gas, sulphuretted hydrogen is formed.—It is evident, therefore, that this gas consists of a volume of hydrogen holding sulphur in solution; and since its specific gravity is 1.1912, and that of hydrogen 0.0737, it follows that it is composed by weight, of 93.87 sulphur + 6.13 hydrogen.

§ 154. *Hydriodic Acid Gas.*—Agitate a certain quantity of the gas in a tube over mercury; the acid will be decomposed, a solid iodide of mercury produced, and a volume of hydrogen evolved, equal to half that of the acid gas. Now, since the specific gravity of this gas is 4.375, and that of the vapour of iodine, 8.678, it must be formed by weight of 100 iodine, and 850 hydrogen; and by volume, of one of hydrogen and one of vapour of iodine, in their natural state of condensation.

§ 155, *Hydrochloric Acid Gas.*—Heat some pure grain tin in a small retort, containing a certain quantity of the gas, over mercury. The tin will combine with the chlorine, and form the substance formerly called Libavius's liquor, and a volume of hydrogen gas will be set free, equal to half the volume of hydrochloric acid gas employed.

If a mixture of equal volumes of perfectly dry chlorine and hydrogen be detonated together, two volumes of hydrochloric acid are the result, consequently the gases combine without any condensation, and the specific gravity of hydrochloric acid, must be equal to half the sum of the specific gravities of its elements, that is $\frac{2.4713 + 0.0737}{2} = 1.2725$. Hence hydrochloric acid gas consists of equal volumes of chlorine and hydrogen.

A detailed history of the controversy respecting chlorine, and of the facts which led Sir Humphry Davy to the establishment of its uncompounded nature (*a*) would be impertinent in this place; but since an attempt has been lately made by Dr. Ure to revive the subject, and to confirm the opinion of Dr. Murray, who contended in support of the former theory, a few words seem necessary. Dr. Murray's principal opponent was Dr. John Davy; their arguments may be found at length in Nicholson's Journal.

According to the school of Lavoisier, chlorine is a compound body consisting of muriatic acid and oxygen. When hydrogen and chlorine, or as it was called, oxymuriatic acid gas, are detonated together, the hydrogen, combining with the supposed oxygen of the chlorine, forms water, which becomes part of the muriatic acid, to whose existence in an insulated state it is conceived to be essential, and which, on this hypothesis, must consist of an unknown base and water; and could this be proved, the presence of oxygen would be justly inferred in chlorine. Dr. Murray's experiments were chiefly directed to this object, but

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(*a*) The possibility that chlorine might be a simple substance was first suggested by M. M. Gay Lussac and Thenard (unless with Sir Humphry Davy we rather ascribe it to Scheele) but we are indebted to our illustrious fellow countryman for the *proofs* which confirmed the supposition.

ineffectually. Dr. Ure, however, has recently asserted, that if muriate of ammonia in vapour, or muriatic acid gas, both completely dry, be passed through a tube containing iron or silver, at a red heat, water is abundantly produced. Sir Humphry Davy repeated the experiment and ascertained that the water was derived from sources not suspected by Dr. Ure.

When muriatic acid gas was passed through flint glass tubes heated red hot, a copious dew was formed; the glass became opaque, and a combination of chlorine and lead sublimed from the hotter into the colder part of the tube: when green glass tubes (which contain no oxide of lead) were used, the dew was less abundant, the surface of the tube became slightly opaque, but no sublimate was formed. When the gas was passed through similar tubes containing clean iron wire, if atmospheric air was present considerable quantities of water were formed, but when such precautions were taken, by filling the whole apparatus with hydrogen, and generating the muriatic acid gas in a retort filled with hydrogen, that no atmospheric air, whose oxygen might form water with the hydrogen of the muriatic acid gas disengaged by the action of the iron, could be present, in this case no more water was produced than in the former instance by the action of the gas on the oxide of lead and alkali in the glass. Like results were obtained with muriate of ammonia, except that it was not altered by being passed through the glass tubes alone, but when metals were present it gave results similar to those afforded by muriatic acid gas.

It has been stated above, that when equal volumes of chlorine and hydrogen are detonated together, two volumes of hydrochloric acid are the result, and when metals act on hydrochloric acid, half its volume of hydrogen is produced. It follows that the other half volume must be chlorine, and consequently if water be produced by the action of metals on hydrochloric acid, either the chlorine or the metal or both must be decomposed. Sir Humphry Davy passed 23 cubic inches of chlorine, freed from its aqueous vapour by hydrochlorate of lime, over red hot iron wire contained in a green glass tube placed within another of flint glass; *not the slightest appearance of moisture was perceptible.* (See Phil. Trans. 1818, p. 169.)

Thus the source of the water in Dr. Ure's experiment, is satisfactorily demonstrated to have been the oxide of lead and alkali in the glass, and the atmospheric air in the apparatus, all of which are decomposed by the compound affinities of the hydrochloric acid gas and these substances.

In the fourth edition of his system of chemistry, just published, (vol. ii. p. 429.) Dr. Murray remarks on the preceding experiment of Davy, " These causes, I believe, have little or no influence on the result. The water does not appear until after the air in the tube has been entirely expelled by the muriatic acid gas. And were it even granted, that at a red heat the glass is liable to be acted on by the acid, in the greater number of the experiments I performed, the heat applied was much lower, and the glass did not exhibit the slightest appearance of being acted on. The objection is not better founded than the one formerly maintained, that the water is derived by absorption from the atmosphere."

From the definite nature of chemical compounds, it is difficult to conceive how water can be produced by the action of hydrochloric acid gas, on clean iron or silver, even supposing it to be actually contained in, and essentially necessary to the existence of the acid in the gaseous state. Acids do not combine with the pure metals, but with their oxides. Hydrochloric acid, on the hypothesis of Dr. Murray must consist of an atom of muriatic acid and one of water; when made to act on pure silver or iron, if the analogies, so strongly insisted on, between hydrochloric and the common acids really hold, the water must first be decomposed by the metal to form the oxide, before the acid can enter into union with it; but, since to assume that each atom of acid combines with more than one atom of water, would be purely gratuitous and untenable, whence can the oxygen be derived to constitute the water they pretend to be given off? It seems evident, that, even on the old hypothesis, hydrogen at most ought to be evolved.

§ 156. *Fluosilicic Acid Gas.*—This gas was analysed by Dr. John Davy, by passing it into liquid ammonia, which precipitates the whole of the silica. According to his analysis it is composed of fluoric acid 38.6, silica 61.4.—(Phil. Trans. 1812.) It might also be accomplished by dissolving 100 cubic inches of this gas in water, pouring an excess of subcarbonate of soda into the solution, boiling and filtering it.—All the silica deprived of its acid would remain on the filter; when dried and calcined it might be weighed, and its weight, deducted from the weight of the gas, would give us that of the acid.

§ 157. *Fluoboric Acid Gas.*—There is not hitherto any process known by which the proportions of the elements of this gas may be certainly determined.—It is decomposed by heating potassium in it. Boron and fluate of potassa are the results.

To distinguish the Mineral Acids contained in a Mixed Solution of those Bodies in Water.

§ 158. Only five of the acids soluble in water can exist together in solution, even at slightly elevated temperatures:—these are the boracic, carbonic, phosphoric, fluoric, and fluoboric; *(a)* the properties of all the rest are affected by their mutual action.

A. *Phosphorous* and *Hypophosphorous Acids* are altered by the action of the nitric, nitrous, chloric, iodic, and perhaps chromic and molybdic acids.

B. *Sulphurous Acid*, by the nitrous, nitric, chloric, iodic, chromic, molybdic, and hydrosulphuric, or sulphuretted hydrogen. *(b)*

C. *Sulphuric*, by the hydriodic, and sometimes by sulphuretted hydrogen. (See K)

D. *Nitric*, by the phosphorous, hypophosphorous, sulphurous, hydrochloric, hydriodic, and sulphuretted hydrogen.

E. *Nitrous*, by the phosphorous, hypophosphorous, sulphurous, sulphuretted hydrogen, hydriodic, and probably chloric.

F. *Chloric*, by the phosphorous, hypophosphorous, sulphurous, hydrochloric, sulphuretted hydrogen, and probably hydriodic and nitrous.

G. *Iodic*, by the phosphorous, hypophosphorous, sulphurous, hydrochloric, hydriodic, and sulphuretted hydrogen.

H. *Hydrochloric*, by the nitric, chloric, iodic, chromic, molybdic.

(*a*) I omit the tungstic and columbic acids, since they are insoluble in water.

(*b*) I retain the name of sulphuretted hydrogen for the reasons given. (9) (6) Its properties clearly rank it with the acids.

I. *Hydriodic*, by the sulphuric, nitric, nitrous, iodic, and probably chloric, chromic, and molybdic.

K. *Sulphuretted Hydrogen*, by the sulphurous, nitric, nitrous, chloric, iodic and arsenic; sometimes by the sulphuric, and probably by the chromic, and molybdic. (*a*)

L. *Arsenic Acid*, by sulphuretted hydroden after being some time in contact with it.

M. *Chromic* and *Molybdic Acids*, by the sulphurous, hydrochloric, and probably hydriodic, phosphorous, and hypophosphorus acids, and sulphuretted hydrogen.

§ 159. Not only the temperature, but also the quantity of water in which the acids are supposed to be dissolved, in many instances, modifies the results. Thus sulphurous acid and sulphuretted hydrogen may exist together when their solutions are largely diluted, but when concentrated they immediately decompose each other. (*b*) The same observation applies to the

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(*a*) The decomposition of sulphuretted hydrogen by other acids is always effected by their abstracting its hydrogen, which combines with the oxygen of the decomposing acid, and its base, together with the sulphur of the sulphuretted hydrogen, are set free. Sulphuric acid requires to be highly concentrated, and a considerable length of time to effect the decomposition of sulphuretted hydrogen, and the latter must be in its gaseous form.

(*b*) I may mention here incidentally, that Dr. Thomson has given a communication in the Annals of Philosophy, for December, 1818, p. 441, on the mutual action of dry sulphurous acid, and sulphuretted hydrogen gases, from which it appears that the subject has not hitherto been well understood. He found 12 measures of sulphuretted hydrogen gas completely absorbed by 8 of sulphurous acid. The substance deposited was not sulphur, though in appearance greatly resembling it, but a peculiar acid compound which appears to consist of sulphur, oxygen, and hydrogen. There is no proof of any water being formed in the process, as Dr. Thomson could not separate any from it, either by heat iodic and hydriodic acids. Sulphurous acid also takes oxygen from concentrated nitric almost immediately on their coming in contact, but they may be mixed in considerable quantities in water, without undergoing any change, at least at common temperatures.

§ 160. It will be convenient for the solution of the proposed question to arrange the acids into two series, as follows:—

Acids of the First Series.	*Acids of the Second Series.*
Boracic.	Carbonic.
Phosphoric.	Sulphurous.
Phosphorous.	Nitrous.
Hypophosphorous.	Hydrochloric.
Sulphuric.	Hydriodic.
Nitric.	Fluoboric.
Chloric.	Hydrofluoric.
Iodic.	Sulphuretted hydrogen.
Arsenic.	
Molybdic.	
Chromic.	

To ascertain if any of the acids of the second series be present in the mixture, saturate it by degrees, with pure hydrate of potassa, evaporate to dryness, transfer the residuum to a flask, add sulphuric acid, and receive the gas which may be evolved over mercury. The

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or any other method he could devise. Two atoms of sulphurous acid contain two atoms of sulphur, and four of oxygen; three of sulphuretted hydrogen contain three of sulphur and three of hydrogen.—If water were formed, one atom of oxygen must remain uncombined, so that its production is equally inconsistent with theory as with experiment.

nature of this must then be examined as directed in the preceding pages of this volume (§ 14.)

The hydriodic and nitrous acids will be decomposed in the process, but their presence will nevertheless be ascertained with equal certainty by the first producing the beautiful violet vapour of iodine, the second, deutoxide of azote, which may easily be separated from the other gases by an alkaline solution (§ 27), and will instantly assume a reddish yellow colour by contact with atmospheric air or oxygen.

A difficulty however may occur: if vapour of iodine be disengaged by the action of sulphuric or hydriodic acid, the former must necessarily be in part converted into sulphurous acid (*a*.) How are we to ascertain, in that case, if sulphurous acid be contained in the mixture? One of the simplest methods is to decompose a fresh portion of the alkaline salts by a solution of phosphoric acid; if sulphuric acid gas be still evolved, it must have formed part of the mixture. Lastly, it is possible, that sulphuric acid may decompose some sulphuretted hydrogen, but the characters of the latter, are so decidedly marked, that it is always readily distinguished from every other substance.

(*a*) It is not supposed that the iodine can arise from iodic acid, which requires a much higher temperature than is employed in this process for its decomposition; further, sulphurous and hydrochloric acids, immediately throw down iodine from iodates, but not from hydriodates, whereas chlorine, nitric acid, &c. precipitate it from hydriodates, and not from iodates. Moreover, since the hydriodic and iodic acids, mutually decompose each other, it will always be easy to discover, whether, in the experiment quoted, the iodine be derived from iodic or hydriodic acid.

§ 161. Having examined the mixture, for the acids of the second series, those of the first must next be looked for. The mixture contains,

A. *Sulphuric Acid;* if the precipitate it forms with nitrate or hydrochlorate of barya be insoluble in an excess of nitric or hydrochloric acids, and when calcined with charcoal, acquires the taste and smell of rotten eggs.

B. *Nitric Acid;* if, when deprived by heat of the nitrous acid it may contain, on being made to act on copper filings, deutoxide of azote be evolved.

C. *Iodic Acid;* if sulphurous and hydrochloric acids, and sulphuretted hydrogen immediately precipitate iodine, and if the two former produce the same effect, after the mixture is neutralized by potassa.

D. *Chloric Acid;* if, the mixture being saturated with potassa and evaporated to dryness, the residual salt occasion bright scintillations when thrown on burning charcoal; and when heated with dilute sulphuric acid, it gives out oxygen and chlorine, or at least the latter gas (*a*).

E. *Boracic Acid;* if the mixture when slightly supersaturated with potassa, deposits white scaly crystals, by the action of hydrochloric or sulphuric acid, which vitrify by a strong heat.

F. *Molybdic Acid;* if in the preceding experiment, a precipitate be formed, which when digested in boiling water, and a lamina of tin or zinc is immersed in it, the liquid assumes a blue colour; and if it also gives a yellow precipitate with nitrate of lead.

(*a*) Hydrochloric and chloric acids are incompatible with each other in the same solution. If the first series of experiments therefore have proved the presence of hydrochloric acid, the chlorine evolved must be derived from that source.

G. *Arsenic* or *Arsenious Acids*; if neutralized by potassa, evaporated to dryness, mixed with charcoal powder and calcined in a retort, a metal sublimes, having the properties of arsenic (§ 41 G.)

H. *Chromic Acid.*—To discover the presence of this acid, first treat the mixture with an excess of nitric acid, to prevent the chromic acid from passing to the state of oxide, then heat it in order to expel the gaseous acids, and neutralize it by an alkali; if the solution contain chromic acid, it will precipitate nitrate of silver crimson, acetate of lead yellow, and acid nitrate of mercury red, and the last will become green by calcination.

I. Either of the *Acids of Phosphorus.*—Evaporate the mixture nearly to dryness, dilute it with water, and saturate it with ammonia. If an acid with base of phosphorus be present, hydrochlorate of lime will occasion a precipitate, which being decomposed by sulphuric acid, and filtered, and the clear liquor evaporated to a syrup, and then mixed with charcoal powder and distilled in a retort, will yield phosphorus.

Analysis of a Mixture of Sulphuric, Nitric, and Hydrochloric Acids, (a).

§ 162. A. Pour an excess of nitrate of barya into the solution, which will throw down all the sulphuric acid in combination with its base. The weight of the sulphate of barya when well washed, dried, and calcined, will give that of the sulphuric acid; 100 parts

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(a) These acids are the most frequently found mixed together. The nitric and hydrochloric acids are supposed to be too much diluted to decompose each other.

of sulphate of barya indicate 34 parts of sulphuric acid.

B. For the quantity of hydrochloric acid, add an excess of nitrate of silver to the solution, collect the chloride, wash, dry, and weigh it; 100 parts of chloride of silver indicate 24.5 of chlorine, and consequently 25.27 of hydrochloric acid.

C. For the nitric acid, first digest an excess of oxide of silver in the mixture, for about half an hour, shaking it occasionally: then decant the liquid, wash the residuum and add the washings to the liquid. Next drop in a solution of barya water, till it cease to occasion any further precipitate; filter, and wash the precipitate, adding the washings, as before, to the mixture; then saturate the filtered liquid with a further portion of barya water, and evaporate the whole to dryness. The oxide of silver, and the first portion of barya, will separate the hydrochloric and sulphuric acids, and the second portion will combine with the nitric acid. The nitrate of barya, after being well dried, at a heat below incipient redness, will give that of the nitric acid: 100 parts of nitrate of barya indicate 40 parts of nitric acid.

CHAPTER THE FIFTH.

Analysis of Mineral Salts.

DIVISION THE FIRST.

To determine the Nature of any particular Salt.

§ 163. The genus to which the salt belongs must be first ascertained. The genera are 27 in number, namely:—

First Series.

1. Carbonates
2. Sulphites
3. Sulphuretted Sulphites
4. Nitrites
5. Chlorates
6. Fluates
7. Fluoborates
8. Chlorocarbonates
9. Hydriodates
10. Hydrochlorates
, Hydrosulphurets

Second Series.

12. Iodates
13. Nitrates
14. Sulphates
15. Borates
16. Phosphates
17. Phosphites
18. Hypophosphites
19. Arseniates
20. Arsenites
21. Chromates
22. Molybdates
23. Tungstates
24. Columbates
25. Antimoniates
26. Antimonites
27. Seleniates

§ 164. If the salt effervesce with sulphuric acid at the common temperature, or when slightly heated, it belongs to the first series, and its genus will be known by the nature of the gas disengaged.

Nitrites give off a red gas.

Chlorates a greenish yellow gas.

Sulphites are known by the odour of the gas, as are also the *Hydrosulphurets.*

Carbonates give a colourless gas, with a slightly pungent odour, which does not affect the transparency of the air.

The white acid vapours which arise from the *hydrochlorates*, *chlorides*, *(a) fluoborates*, *fluates*, and *chlorocarbonates*, forbid their being confounded with any other (*b*) salts, and by collecting the gases over mercury they may be individually distinguished. If the salt be a fluate, the gas will deposit white flakes when absorbed by water; if a fluoborate, it will blacken paper placed in contact with it; if a hydrochlorate or chloride, its gas will dissolve entirely in less than one-hundredth part of its volume of water, and the solution will give a precipitate with nitrate of silver, soluble in ammonia, and insoluble in nitric acid; lastly, if the salt be a chlorocarbonate, its gas will be composed of two parts of hydrochloric, and one of carbonic acid, and when placed in contact with a little water, the first will be absorbed, and the other retain its gaseous state.

The characters of the *hydriodates* are also distinctly marked. By sulphuric acid the hydriodic acid is dis-

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(*a*) No distinction is made here, between the hydrochlorates and chlorides, but to prevent confusion, it should be remembered, that most of the hydrochlorates when dry, are true chlorides, and when the latter are dissolved in water, they again become hydrochlorates. All the chlorides are decomposed by concentrated sulphuric acid, and afford hydrochloric acid, except chloride of silver. (Note by M. Thenard.)

(*b*) Hydriodic acid gas also exhales white vapours, but when the hydriodates are decomposed by sulphuric acid, sulphurous gas, and vapour of iodine, are the result.

engaged and decomposed, and sulphurous acid gas, distinguishable by its smell, and iodine, partly in the state of vapour so remarkable for its violet colour, are obtained.

Chlorine and nitric acid also separate iodine from the hydriodates.

§ 165. If the salt do not effervesce with sulphuric acid at the usual temperature, nor when heated, it belongs to the genera of the second series.

If a *nitrate*, sulphuric acid will disengage white vapours from it without effervescence, and if some copper filings be added, red vapours, with effervescence, will be evolved. When the salt is thrown on ignited coals, it renders the ignition more vivid. The chlorates, and some of the iodates also possess this property.

If the salt be a *sulphate*, by boiling one part of it for some time, with one and a half or two parts of nitrate of barya, in eight or ten parts of water, sulphate of barya will be precipitated; this, when heated red with an equal weight of charcoal, is converted into a sulphuret, which if moistened has the taste and odour of rotten eggs.

The *iodates* are all insoluble, or nearly so, in water; solutions of sulphurous acid, and sulphuretted hydrogen decompose them, and separate iodine, which may be rendered evident by collecting the precipitate and heating it in a flask. Hydrochloric acid also decomposes them, its hydrogen unites with the oxygen of the iodic acid, water is formed, and chlorine evolved, part of which flies off, and the rest combines with the iodine. The iodates are also decomposed by sulphuric acid, at a temperature of about 400°, oxygen gas and vapour of iodine are disengaged; chlorine does not produce any change in them. They are all decomposed by a low red heat, generally with disengagement of oxygen and iodine, but some give off only oxygen.

§ 166. If the salt under examination neither effervesce by the action of strong sulphuric acid, nor belong to the genera of nitrates, sulphates, or iodates, it is one of the twelve last in the list, and its acid must be combined with potassa, soda, or ammonia, unless already united to either of these bases. *(a)*—For this purpose dissolve the salt in water, and add a solution of subcarbonate of potassa or soda till it occasion no further precipitate, which being separated by the filter, the alkaline salt will remain in solution; but if the salt be insoluble it must be reduced to powder, and boiled with 8 or 10 parts of water, and 2 or 3 of fixed alkaline sub-carbonate, by which it will be wholly or partially decomposed. In either case saturate the filtered liquor with acetic acid, and evaporate it to dryness; then heat the residuum in alcohol, which will dissolve the alkaline acetate, and generally leave the salt, arising from the combination of the alkali with the acid under examination, untouched. *(b)* Thus a borate, chromate, &c. of potassa or soda, distinguished by the following characters, will be obtained:—the *chromate*, the only one of these salts that is coloured, is yellow; it precipitates acetate of lead

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(*a*) The salts with alkaline bases are soluble in water, and their solution is not precipitated by alkaline sub-carbonates.

(*b*) Should the whole residuum be soluble in alcohol the carbonate must be converted into a sulphate instead of an acetate, which will be insoluble in that menstruum; but care must be taken not to add an excess of sulphuric acid, lest the new salt be decomposed. The alkaline *hypophosphites* are probably the only salts under consideration soluble in alcohol.

bright yellow, nitrate of silver violet, and acid nitrate of mercury red; this precipitate yields oxide of chrome by calcination. If nitric or hydrochloric acid be poured into a concentrated solution of a *borate*, the acid is instantly separated, and falls down in the form of small scales possessing characteristic properties. (§ 104.)

Sulphuric acid throws down molybdic acid in form of a powder from the solution of a *molybdate*; a plate of tin immersed in the solution turns it blue.—From the solution of a *tungstate*, either of the strong acids occasions a white flocculent precipitate, which becomes yellow by the action of boiling acid, and is wholly converted into tungstic acid. An *arseniate*, or an *arsenite*, mixed with half its weight of charcoal, and heated in a retort, is decomposed, and arsenic disengaged, which condenses on the neck of the vessel.—Those salts are distinguished from each other as follows:—*Arsenites* precipitate sulphate of copper green, nitric acid separates a white powder from them, and when mixed with hydrosulphuret of potassa or soda and an acid, orpiment is deposited.—*Arseniates* precipitate sulphate of copper blueish white, and acids and hydrosulphurets produce no sensible change on them, at least for the space of some minutes. (a) Sulphuric, nitric, and hydrochloric acids precipitate columbic acid, from the *columbates*, in the form of a white powder. (§ 120.)

The *phosphate*, *phosphite*, and *hypophosphite* of

(a) Nitrate of silver is the readiest test to distinguish these acids.—With *arseniate* of potassa it gives a brownish red precipitate; with *arsenite* one of an orpiment yellow colour.

soda may be distinguished as follows:—the *phosphate* crystallizes in rhombs, is efflorescent, and insoluble in alcohol; distilled with a little sulphuric acid, no hydruret of phosphorus is disengaged. With nitrate of lead it gives a white precipitate, from which phosphoric acid (whose characters are already stated, § 105) may be obtained by means of sulphuretted hydrogen in the manner following:—diffuse the phosphate of lead through twelve or fourteen times its weight of water, and pass gradually into it an excess of sulphuretted hydrogen gas; water and an insoluble sulphuret of lead will be formed, the latter falling down in dark brown flakes, whilst the disengaged phosphoric acid will remain in solution, and may be obtained by filtering and evaporating the fluid.

The *phosphite* of soda is insoluble in alcohol; when boiled with an excess of sulphuric acid, hydruret of phosphorus is disengaged.—Heated with nitric acid, the salt is converted into phosphate, and red fumes of nitrous acid vapour are evolved.—The excess of nitric acid is then to be saturated by an alkali, after which the phosphoric acid may be separated by nitrate of lead, &c. in the manner just stated.

Hypophosphite of soda is very deliquescent, very soluble in alcohol, and like the phosphite, affords hydruret of phosphorus by the action of sulphuric acid: it also is converted into phosphoric acid by nitric acid.

Antimoniate of potassa is a white powder with an acid and slightly metallic taste, nearly insoluble in cold, but very soluble in boiling water; the hot solution deposits nothing on cooling, it becomes syrupy by evaporation, and a very light granular powder separates from it; evaporated to dryness it leaves a brittle white enamel. The properties of *antimonite* of potassa are very similar.

Seleniates.—Selenic acid is expelled from its combinations by the strong and very fixed acids, as the sulphuric, phosphoric, arsenic, and boracic, but it takes silver from nitric acid, and lead from nitric and hydrochloric.—Berzelius considers its affinity for bases as about equal, or perhaps rather inferior to that of arsenic acid: it forms only sub-salts with the alkalies, which have an alkaline taste. All the neutral seleniates formed with other bases are insoluble, or very sparingly soluble in water, and in these salts the oxygen in the acid is double that in the base, for 100 parts of selenic acid contain 28.73 of oxygen, and neutralize a quantity of base containing 14.37.—Selenic acid also forms super-salts, of which there are two degrees: the biseleniates are very soluble in water, and contain twice as much acid as the neutral salts.—The alkaline biseleniates have acid properties, and there is no intermediate salt between these and the sub-salts.—The quadriseleniates contain four times as much acid as the neutral salts, but the existence of these salts is not so fully established as that of the former.—The seleniates are in general decomposed by a moderate heat.—The alkaline seleniates, and those with bases of the alkaline earths, mixed with charcoal powder and heated red, are decomposed without detonation.—Carbonic acid and oxide of carbon are formed, and some selenium sublimes, but the greater part remains united to the base. From the other earthy seleniates, similarly treated, all the selenium flies off as it loses its oxygen.—The metallic seleniates are in the same manner reduced to the state of selenurets.

To ascertain if a salt be a *seleniate*, it will be sufficient to treat it with sulphuric acid, evaporate to dryness, and heat the residuum in a retort over a spirit lamp; the selenium will sublime, and exhibit the appearance described in § 38. F.

It is taken for granted in the preceding sections, that the salt contains a mineral acid, which is easily ascertained, prior to more elaborate experiments, by heating a small portion on a slip of platina foil in the flame of a spirit lamp. If the acid belong either to the vegetable or animal kingdom, it will blacken and be decomposed.

§ 167. The genus being ascertained by the preceding methods, the species must next be determined.

If a salt be soluble in water, and neither the alkalies, nor alkaline carbonates nor hydrosulphurets render the solution turbid, its base must be alkaline. If *ammonia*, it will disengage a pungent odour on being mixed with powdered quicklime and water;—if *potassa*, its saturated solution will precipitate platina from a concentrated solution of that metal, and also give a precipitate with a strong solution of tartaric acid;—if *soda*, it will neither exhale a pungent odour with lime, nor give a precipitate with solution of platina or tartaric acid.—If *lithia* be the base, it will have no action on solutions of platina, nor give any precipitate with tartaric acid. The striking characteristic of this alkali, is the great fusibility of its salts. The sulphate, nitrate, and hydrochlorate fuse below a red heat;—the carbonate just at incipient redness;—the hydrochlorate of lithia is extremely deliquescent, and the nitrate also, but in a less degree. The nitrate and hydrochlorate tinge the flame of alcohol of a beautiful crimson colour, not unlike that afforded by the salts of strontia, but it is seen in its greatest splendour by decomposing acetate of lithia in a small capsule over a spirit lamp; soon after the salt begins to blacken, it takes fire and burns with an intensely deep crimson flame.

If the alkalies, their carbonates, or hydrosulphurets occasion a precipitate in the solution, the base of the salt under examination cannot be alkaline. In this case add an excess of alkali, or alkaline carbonate. (*a*)

If the salt be insoluble reduce it to fine powder, and boil it with 10 or 12 parts of water, and 3 or 4 of subcarbonate of potassa: if that quantity of alkali be not sufficient to decompose it entirely, decant the liquor, or filter it, and treat the remainder with a fresh portion of alkali, (*b*) after which the deposit which the salt affords must be washed with a large quantity of water and collected. This deposit is the oxide or carbonate sought; its nature must be determined as stated, (§ 74, et seq.) except that the carbonate should first be calcined with a little lamp-black at a red heat, in a small retort, to disengage the base, and ascertain whether it be soluble in water, acrid, caustic, or alkaline, that is, whether it be barya, strontia, or lime. These three alkaline earths are easily distinguished, by the solutions of their neutral

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(*a*) A carbonate must be used if the pure alkali do not render the salt turbid, or an excess of it redissolve the precipitate.

(*b*) It will seldom happen that it is necessary to employ sub-carbonate of potassa a second time. The decomposition is compleat when the residuum dissolves with effervescence in nitric acid, provided always that the oxide be capable of combining with carbonic acid.

nitrates or hydrochlorates giving no precipitate with pure ammonia or its hydrosulphuret. (a)

The salts with base of morphia have not been noticed in the preceding sections; they are not likely to be often met with, nor have they been very attentively examined; it will be right, however, to subjoin a short account of their general leading properties.

Most of the salts of morphia are neutral, and in that state are all soluble in water, and decomposable by potassa, soda, and ammonia, which precipitate morphia from their solutions: a red heat decomposes them and destroys the base. They have a strong action on the animal system, but not so violent as that of uncombined morphia. The sulphate of morphia crystallizes in a dendritical form; the hydrochlorate assumes a plumose appearance, and is less soluble than the sulphate, which very readily dissolves in water. The nitrate crystallizes in prisms, radiating from a common centre; the carbonate in short prisms; the acetate and tartrate also in prisms, and the submeconiate, (the state in which it is found in nature, constituting the narcotic principle,) in oblique prisms. The acetate is very soluble in water, the submeconiate but sparingly so.

(a) The decomposition of some insoluble salts by the alkaline carbonates is very difficult, but they are all acted on by sulphuric acid, with which their bases form insoluble salts, and these sulphates are easily decomposed by carbonate of potassa; in this case, therefore, it is best to convert the salt into a sulphate. By not dissolving all the carbonate produced, we are sure not to dissolve any portion of the salt we wish to decompose; it will remain in the residuum rather than the carbonate.

DIVISION THE SECOND.

To determine the proportions of the Elements of Salts.

§ 168. The *First Process* is by synthesis, or the direct combination of the constituent principles. Suppose the salt in question to be sulphate of lime, or gypsum, which, as well as its base, is sparingly soluble: take 150 or 200 grains of pure dry quick lime, slake it in a small basin, diffuse it through water, and add by degrees, weak sulphuric acid, stirring the mass with a spatula; when the acid is in considerable excess, evaporate the whole to dryness, and calcine the sulphate at a red heat, to drive off the water and excess of acid: then, deducting the weight of the lime from that of the sulphate, the remainder is the weight of the acid (*a*). The analysis of the sulphates of strontia, magnesia and barya, may be made in the same manner (*b*).

Suppose both the salt and its elements to be soluble, as sulphate of ammonia; take two weak solutions, one of the acid, the other of the alkali, containing known quantities of real acid and alkali, and ascertain, by adding the alkali cautiously to the acid, how much of it is necessary to neutralize 2000 or 3000 grains of the acid.

(*a*) It is necessary to add an excess of acid to the lime, otherwise we cannot be sure that it is perfectly neutralized, on account of the pasty mass which it forms.

(*b*) As the sulphate of magnesia is soluble, merely sufficient acid to dissolve the magnesia, need be added, and the same with all other bases that form soluble sulphates; if the sulphate be decomposed by heat, the temperature must be regulated accordingly.

Lastly, if the elements of the salt be gaseous, as is the case with hydrochlorate of ammonia, measure a certain volume of the acid gas over mercury, and pass ammoniacal gas to it by degrees, till the whole of the acid is absorbed. In this manner the proportion in which the two gases combine is easily determined, and from it, and their specific gravities, may be calculated the weights of acid and base in the salt.

§ 169. *Second Process*, by analysis.. This is the reverse of the former; it consists in separating the elements of the salt from each other, and finding the weight of one or both.

If the salt be not decomposable by heat, calcine it to redness, otherwise it must be dried by exposing it to the temperature of boiling water, or by placing it on hot sand in a vacuum, near a substance having a strong attraction for water. Most of the oxides are insoluble in water, and may be separated from their acid by the alkalies, provided that the oxide be not soluble in excess of alkali, nor capable of absorbing carbonic acid, or at least that it part with it again by heat, without undergoing any other change. Such are the bases of the salts of magnesia, alumina, glucina, yttria, zircona, the tritoxide of iron, deutoxide of copper, &c. &c.

As most oxides are insoluble in water, so all the acids on the contrary are soluble in that fluid, except the tungstic, columbic, antimonic and antimonious; and even on the columbic, water has a decided action. Consequently no acid of any salt can be insulated, by precipitation by another acid, except the four just mentioned (*a*).

(*a*) Boracic acid, is, indeed, precipitated from a concentrated solution of subborate of soda, by sulphuric acid.

There are few acids which do not form with some base, and few bases which do not form with some acid, an insoluble salt. Sulphate of soda, and hydrochlorate of barya may be quoted as instances. Dissolve a certain quantity of either salt in water, and add to it a solution of the other in excess, a precipitate of sulphate of barya will be obtained, containing in one case all the acid of the sulphate, in the other all the barya of the hydrochlorate. Collect the precipitates, wash, dry and calcine them. 100 parts of sulphate of barya, contain 34 of sulphuric acid, and 66 of barya. After this manner many salts may be analysed.

To determine the weight of a weak gaseous acid, not very soluble in water, put the salt in a flask, to which a spiral tube is adapted, and add to it a sufficient quantity of nitric acid, of the specific gravity of 1.15; when the decomposition is compleat, deduct from the sum of the weights of the flask, the acid, and the salt, that of the flask and its remaining contents; the loss of weight indicates the quantity of gaseous acid expelled. The proportion of carbonic acid in the carbonates, may be estimated in this manner (*a*).

Lastly, if the oxide be fixed, and undergo no change at a high temperature, or such only as can be taken account of, and the acid ŏr its elements be volatile, the quantity of the former may be known, by simply calcining the salt in a platina crucible. The acids and oxides of the greatest part of the nitrates, nitrites, and carbonates, may be analysed in this manner.

The greater number of salts contain water of crystallization; in order therefore to make an accurate

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(*a*) The small quantity of carbonic acid, which remains in solution, is very nearly balanced by the aqueous vapour, carried off with the disengaged portion, if a great excess of nitric acid be avoided.

analysis of such, the quantity of water must be ascertained, as well as that of the acid and base.' If the salt be not decomposed by high temperatures, it is merely necessary to heat a given weight of it to redness, in a platina crucible, the tare of which has been previously accurately taken, and ascertain how much it loses by the operation. Care must be taken that none of the salt be lost in the process, either by boiling up over the sides of the crucible, as will be likely to happen with sulphate of soda and such as contain a very large quantity of water of crystallization, or by decrepitation, as with the sulphate of potassa, or common salt. This must be obviated by heating them at first, very gradually, on the sand bath, or by steam, with a cover adapted to the crucible, till the salt is reduced to a solid state, or has ceased to emit any crackling noise, after which it is to be heated red. In all cases it is well to reduce the salt if it can be done, to a fine powder and to expose it for half an hour or longer to a temperature between 150° and 200°, in order to free it from any adhering moisture, and bring it to a standard state of dryness.

' If a high temperature would decompose the salt, destroying or volatilising one of its constituents, the following method recommended by Dr. Thomson, may be adopted.

Suppose the salt to be phosphate or tungstate of ammonia, "Weigh out 50 grains of it, and put it into a small retort. This retort must be fitted to a very small receiver, containing a saturated solution of caustic potash. Before the experiment begins, the retort, and likewise the receiver, must be accurately weighed, and their weights noted down. Heat is then gradually applied to the bottom of the retort, till the salt becomes visibly red hot. The whole is then weighed a second time. The loss of weight sustained by the retort is equivalent to the weight of the base of the salt, and to that of the water of crystallization which the salt contained. The receiver will have increased in weight, and the increase will be just equal to the water of crystallization of the salt.

This increase subtracted from the loss of weight sustained by the retort, will give the weight of ammonia which the salt contained." (Supplement Ency. Brit. vol. iii. page 506.)

If the base be indestructible, but the acid incapable of resisting the action of a red heat, as is the case with acetate of potassa, and all the salts with vegetable or animal acids, proceed as follows: "Mix 50 grains of the salt, acetate of potassa for instance, with an excess of sulphuric acid in a platinum crucible, and expose the mixture at first to a low heat, which is to be very slowly raised till the crucible is heated intensely red hot. The heat of a common fire will not be found sufficient to dissipate the excess of acid, unless it be urged by a pair of bellows. By this process, the acetate of potash is changed into sulphate of potash. Ascertain the weight of this new salt, $\frac{6}{11}$ths of it are potash. Thus we obtain the weight of the potash contained in the 50 grains of acetate of potash. Let this weight be $= a$. Now, the weight of an atom of acetic acid is 47.82, that of potash 45. Hence we have $45 : 47.82 :: a :$ quantity of acetic acid in 50 grains of acetate of potash $= x$.

From this proportion we obtain $x = \frac{47.82\, a}{45}$. Now it is obvious, that $a + x$ is the amount of the potash and acetic acid in 50 grains of acetate of potash. If we subtract this sum from 50, the remainder will give us the water of crystallization contained in the salt.

"Many of these salts, though incapable of bearing a red heat without decomposition, may be exposed to the heat of boiling water without injury. And in many cases, this temperature is sufficient to remove the whole or nearly the whole of the water of crystallization. Then in many cases this method may be applied with success." (Supplement Ency. Brit. vol. iii. page 506.)

"When both the constituents of a salt are volatile, and when it cannot be exposed even to a moderate heat without volatilization, in such a case we are unable at present to determine the water of crystallization directly. Such is the case with acetate of ammonia. But even in this case we are not without resource; though the only methods which can be followed require uncommon skill and every possible precaution. If we dissolve the acetate of ammonia in water and add potash to the solution (noting the quantity) till we have just driven off the whole of the ammonia, and saturated the acetic acid; knowing the weight of potash employed, we can hence determine the weight of the acetic acid saturated. Knowing the weight of acetic acid, we can deduce from the table of chemical equivalents, the weight of ammonia requisite to saturate it. The weight of the acetic acid being added to that of the ammonia, and the sum subtracted from that of the original quantity of acetate of ammonia experimented on, the remainder will be the weight of the water of crystallization which that salt contains." (Ibid).

§ 170. *Third Process.*—If an iodide, chloride, or sulphuret, capable of decomposing water, be made to act on that fluid, neutral hydrochlorates, &c. are formed, the oxygen of the water passing to the base, and its hydrogen to the other element of the decomposing compound. Consequently, if the composition of either the acid, or oxide formed, be known, and also that of the iodide, the composition of the neutral salt, may be thence deduced; since for every part of hydrogen, denoted by unity, which combines with the iodine, &c. 7.5 of oxygen must unite to the base, and vice versa. This process is clearly applicable only to those salts, whose acids contain hydrogen, (a).

§ 171. *Fourth Process.*—The iodates of potassa, soda, lime, &c., and most of the chlorates, are decomposed by calcination; the whole of the oxygen, both of acid and base flies off, leaviug an iodide or chloride, corresponding to the degree of oxidation of the metal. The loss of weight therefore will give the qnantity of oxygen contained in the iodate, &c. and hence if the composition of the oxides, and of the iodic and chloric acids be known, the proportions in which they unite to form iodates and chlorates will be easily ascertained.

For example, 100 parts of iodate of potassa give off 22.59 of oxygen at a red heat, and 77.41 parts of iodide of potassium remain, containing 18.47 of potassium, which require 3.77 of oxygen to become potassa. The oxide therefore in this case contains 3.77 of oxygen, and the acid 18.82. Consequently iodate of potassa is composed of

Iodic acid	iodine	58.94	77.76
	oxygen	18.82	
Potassa	potassium	18.47	22.24
	oxygen	3.77	
			100.00

(a) Thenard calls these "hydracids," and those containing oxygen "oxacids."

The same method is applicable to the analysis of several of the sulphates, and generally to all salts, whose oxygen being compleatly expelled by heat, the remaining elements enter into fresh union. With the sulphates however, the addition of some substance having a strong attraction for oxygen, as charcoal, is necessary to detach it from its previous combination.

§ 172. *Fifth Process.*—The quantity of acid in all salts, is proportionate to the quantity of oxygen in their bases; hence the composition of the oxides, and of one salt of any genus being known, that of every other species of the same genus (being equally neutral) may be determined by calculation. For instance, sulphate of copper is composed of 100 acid, and 100 oxide, and the oxide contains one-fifth of its weight of oxygen; consequently all the other sulphates must be composed of 100 acid, and a quantity of oxide containing 20 parts of oxygen.

§ 172 bis. Berzelius analysed seleniate of soda by heating the dry salt with twice its weight of hydrochlorate of ammonia, 'till all the excess of the latter, as well as the selenium was driven off, and hydrochlorate of soda only remained. 100 parts of seleniate of soda which had been exposed to a strong red heat, and reduced to powder, afforded by this method, 66.6 of hydrochlorate of soda, equivalent to 35.5 parts of soda: therefore 100 parts of selenic acid, combine with 55 of soda, which contain 14.11 of oxygen; a quantity very nearly half that of the oxygen in the acid.

100 parts of biseleniate of soda, deprived by a gentle heat of their water of crystallization, gave by similar treatment with hydrochlorate of ammonia, 41.66

of hydrochlorate of soda, equivalent to 22.17 parts of soda; consequently 100 of the acid combine in the bi-salt with 28.48 of soda, which contain 7.5 of oxygen; rather more than half the quantity found in the experiment on the seleniate.

It is very difficult to obtain the biseleniates in a dry state, without driving off a portion of the acid with the water.

§ 173. In concluding this part of the subject, I may remark, that, when practicable, the result of one process, should be confirmed by another differently conducted, and in the analysis of a neutral salt, by double decomposition, the quantities of the new products must exactly correspond with the proportions indicated by the elements of the original compound; otherwise the analysis is obviously incorrect. This simple test of the accuracy of our experiments, we owe to M. Richter, who first observed the facts that have since become the foundation of a theory, which has rescued chemistry from the confusion it long was involved in, and has almost elevated it to the rank of a mathematical science. (Note D. Appendix.)

CHAPTER THE SIXTH.

Analysis of Mineral Waters.

§ 174. Waters, which contain so much foreign matter, as to have a sensible taste, and a decided action on the animal economy, are called mineral. Their temperature varies from that of the atmosphere, to almost a boiling heat; and according as it is higher or lower, they have received the denomination of *thermal*, and cold springs. It is not our business to enquire into the remote causes of the remarkable phenomenon of hot springs, but that it must depend on the nature of the strata the waters traverse, from their source to the spot whence they issue, is obvious.

§ 175. The substances hitherto found in mineral waters are,

Oxygen.
Azote.
Carbonic acid.
Sulphuretted hydrogen.
Boracic acid.
Sulphurous acid.
Silica.
Soda.

Sulphates of soda, ammonia, lime, magnesia, alumina, potassa, iron and copper.

Nitrates of potassa, lime and magnesia.

Hydrochlorates of potassa, soda, ammonia, lime, magnesia, alumina, manganese and barya.

Carbonates of potassa, soda, magnesia, lime, ammonia and iron.

Hydrosulphurets of soda and lime.

Sub-borate of soda, and small portions of *vegetable* and *animal* substances.

§ 176. Azote and oxygen are not found in waters of a high temperature, nor the latter even in cold springs, which hold hydrosulphurets in solution.

Most waters contain a small portion of carbonic acid; it abounds particularly in the sparkling waters, as those of Seltzer and Pyrmont, which contain many times their bulk of that gas.

A smell, or taste of rotten eggs, indicates the presence of sulphuretted hydrogen, or of a hydrosulphuret. Sulphurous acid is found in some waters in the neighbourhood of Volcanos.

Boracic acid occurs in some of the Italian lakes.

Silica is contained in the waters of the Guysers and Rykum in Iceland, in those of Carlsbad, and in some others.

Soda in the Guysers and at Rykum.

The *salts* of most frequent occurrence in mineral waters, are the sulphates, hydrochlorates and carbonates of soda, lime and magnesia, and carbonate of iron. The three last carbonates are generally held in solution by carbonic acid. Hydrochlorate and sulphate of ammonia, sulphate of iron, alum, and sulphate of copper, the nitrates of potassa and lime, and borax, are rarely found in them. The three first, like sulphurous acid, belong to some of those in the neighbourhood of Volcanos; sulphate of copper to those which flow through beds of copper pyrites, and borax to some of the lakes of India and Italy.

Nitrate of magnesia, hydrochlorate and carbonate of potassa, and carbonate of ammonia are of still rarer occurrence, if, indeed, ever found in mineral waters; and, although Bergman has announced the existence of the hydrochlorate of barya and manganese, and Dr. Withering that of the hydrochlorate of alumina in some of them, the accuracy of the statement is extremely questionable.

§ 177. A mineral water can never contain all the foregoing substances together; as some of them mutually decompose each other; thus, the sub-carbonate of soda is incompatible with the sulphates, nitrates, and hydrochlorates of lime and magnesia: indeed more than eight ingredients are seldom found in the same water, nor does it often contain a large quantity of any one of them.

§ 178. Mineral waters may be conveniently divided into four classes, according to the ingredient by which their properties are chiefly influenced; namely, hepatic, acidulous, ferruginous, and saline; and sometimes mixed classes must be admitted.

The nature of a water, and most of the substances it contains, may generally be ascertained by simple trials; if a water contain

A. *Sulphuretted hydrogen without a hydrosulphuret*, it will have the smell of rotten eggs, and precipitate solutions of lead black, but it loses both these properties by being boiled.

B. A *hydrosulphuret* is attended with the same smell as sulphuretted hydrogen, but weaker; it also precipitates solutions of lead black; but heat does not destroy either of these properties.

C. *Carbonic acid.*—Waters containing this gas are acidulous, and sometimes sparkling; they redden litmus faintly when fresh, but boiling destroys that property, and disengages a gas, which, passed into lime water, occasions a precipitate of carbonate of lime, soluble with effervescence in very dilute nitric acid.

D. *Sulphates* form with nitrate or hydrochlorate of barya a white precipitate, insoluble in an excess of acid.

E. *Hydrochlorates* produce a white flocculent precipitate with nitrate of silver, insoluble in nitric acid, but soluble in ammonia.

F. *Carbonates of magnesia, lime*, or *iron*.—Waters containing these salts become turbid by boiling; the carbonic acid which holds those substances in solution being driven off. If the precipitate be white, probably no metallic oxide is present.

G. *Carbonate of iron;* with the recent water prussiate of potassa gives a blue precipitate, and tincture of galls a purple one, which, by standing exposed to the air, becomes black. If the water be boiled a yellowish red precipitate is thrown down, and the preceding tests cease to produce any effect on it.

H. *Sulphate of iron.*—The action of prussiate of potassa, or galls, is not suspended by boiling the water.

I. *Carbonate of soda*, or *potassa*.—If a water contain either of these alkalies it will turn syrup of violets green after being boiled, at least when sufficiently concentrated, and if then filtered, and an acid be poured into the clear fluid, carbonic acid gas will be given off, though perhaps it may be necessary to heat the water to render it evident, as, if the carbonate be in very minute quantity, the gas may be retained in solution by the cold fluid.

K. *Calcareous salts.*—Oxalate of ammonia throws down a white precipitate from the recent water, if any salt, with base of lime, be present; but if the water contain only carbonate of lime the test will have no effect after boiling: with all the others the effect is permanent.

L. *Magnesian salts, not carbonates.*—Boil and filter the water, and let it cool; to the clear liquid add bi-carbonate of ammonia; filter, if necessary, and boil again.—If a sulphate or hydrochlorate of magnesia be present the second boiling will produce a second precipitate; or, after the bi-carbonate, instead of boiling, add phosphate of soda, which will throw down a precipitate of the ammoniaco-magnesian phosphate; if this precipitate be suffered to subside to the bottom of the basin, and it be rubbed with the point of a glass rod with some force, traces will be left on the glass not easily effaced.—Pure ammonia also renders solutions of magnesian salts turbid.

M. *Aluminous salts.*—Ammonia threws down a bulky gelatinous precipitate, soluble both in sulphuric acid, and in caustic potassa, which contracts extremely on drying, and cracks in all directions. If a few drops of a solution of potassa be added to the acid solution, octohedral crystals of alum will be obtained, by slow evaporation.

N. *Salts of copper.*—Ammonia gives the water a blue tinge; and a plate of iron immersed in it is very soon covered with a coat of copper.

O. *Ammoniacal salts, not carbonates.*—A water containing these salts leaves a residuum after evaporation, which evolves the pungent odour of ammonia on being mixed with quick lime.

P. *Sulphurous acid.*—Waters holding this acid in solution have generally the smell of burning sulphur; they redden *litmus*, and deposit sulphur by the action of sulphuretted hydrogen. When distilled they yield an acid product, which, if neutralized by soda, and exposed to the air, acquires the property of giving a precipitate with nitrate of barya insoluble in nitric acid.

Q. *Carbonate of ammonia.*—These waters yield an alkaline product by distillation.

R. *Nitrates.*—If a solution of potassa be poured into the water, till no further precipitate falls down, and the liquor filtered and evaporated, a residuum will be obtained which scintillates when thrown on burning coals, like nitre.

When the substances contained in a mineral water are in very minute quantity, it may be necessary to concentrate it considerably by evaporation, to render the effect of the reagents sensible.

§ 179. Only a small number of the preliminary trials enumerated above will be necessary to ascertain the nature of any particular water.—The following method is of general application. It consists in first collecting the gases, and next the solid matter contained in the water: the latter is then to be divided into three portions; the first contains all the substances very soluble in water; the second, those soluble in alcohol, and the third, those insoluble in both.—Thus, an otherwise complicated analysis, is rendered simple and easy.

To collect the Gases.

§ 180. For the quantity of *azote* and *oxygen*, adapt a bent tube to a flask and fill both with water; pass the end of the tube under a jar full of and inverted over mercury, and heat the water till it boils, and all the gas is evolved.—A little caustic potassa, or soda, should be passed up into the jar to absorb any carbonic acid or sulphuretted hydrogen the water may contain; but the alkali must not be introduced, till after the gas is collected, if the water be sulphurous, as the hydrosulphuret of potassa or soda would be liable to absorb a portion of the oxygen gas, if left long in contact with it. Having thus obtained the whole of these gases, their respective quantities must be determined by analysis. (§ 28 A.)

Mineral waters seldom contain so much oxygen and azote as common water.

§ 181. To ascertain the quantity of *carbonic acid;* to a matrass capable of holding about 500 cubic inches, adapt a glass tube, so bent as to pass to the bottom of a jar, containing a mixture of ammonia and hydrochlorate of lime, and through the cork which closes the mouth of the jar insert another bent tube, whose opposite extremity must be immersed in water. Fill three fourths of the matrass with the mineral water, secure all the joints with cement or lute, and heat it gradually till it boils, and continue the ebullition till the whole of the gas has passed over into the alkaline liquor. The carbonic acid will first unite with the ammonia, and the carbonate thus formed will then decompose the hydrochlorate of lime, and a precipitate of carbonate of lime will fall down. This must be carefully collected and dried, and from its weight that of the carbonic acid, and consequently its volume is obtained: 100 parts of carbonate of lime indicate 43.7 parts of carbonic acid, and 100 cubic inches of the gas weigh at the mean temperature and pressure 46.57 grs. *(a) (b)* If the water contain

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(*a*) The objection to this method is the enormous quantity of water required to afford a sufficient portion of carbonate of lime. Very accurate results may be obtained, by simply receiving the gas over mercury, if the process be carefully conducted: in that case a pint of the water, and even less will be quite sufficient.

(*b*) If the water contain any carbonates it is probable that they may be in the state of bi-carbonates, especially if the water contain uncomsulphurous acid add a little acetate of lime before it is heated; it would otherwise be partly volatilized, and a portion of insoluble sulphite of lime be mixed with the carbonate.

§ 182. The quantity of *sulphuretted hydrogen* may be ascertained by a similar process, substituting acetate of lead for the ammonia and hydrochlorate of lime; sulphuret of lead will be formed and precipitate in black flakes; but the carbonic acid, if any, will remain free: 100 parts of sulphuret of lead contain 86.6 of lead and 13.4 of sulphur, and 100 cubic inches of sulphuretted hydrogen gas, at mean pressure and temperature, weigh 36 grains; it is easy, therefore, from the weight of the sulphuret to find the quantity of gas. (*a*)

The two processes just described, must of necessity be adopted, when a water contains both carbonic acid, and sulphuretted hydrogen; but if it contain only one of them, it is more simple to fill four-fifths of a flask with it, and adapt a bent tube to its neck, which must pass under a mercurial jar, and boil the water for two or three minutes: all the air and carbonic acid, or sulphuretted hydrogen, with a small portion of water, will pass into the jar, and being measured,

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bined carbonic acid; and since these give off half their acid at 212°, part of the gas may be derived from that source. This will be ascertained by comparing the quantity of carbonic acid gas evolved, with that of the carbonate obtained in the course of analysis: (§ 186. C.) the bi-carbonates contain twice as much carbonic acid as the carbonates.

(*a*) The hydrosulphurets give off sulphuretted hydrogen by heat, but it is easily to know if a water contain *only* sulphuretted hydrogen, by its not exhaling the peculiar fetid odour of that gas, on adding hydrochloric acid to a portion of it, that has been boiled; whereas, if a hydrosulphuret be present, it will be abundantly sensible.

may be separated by caustic potassa, which will absorb the acid gas, but have no action on the common air. The condensed aqueous vapour, will indeed retain a small portion of the carbonic acid, or sulphuretted hydrogen, of which it will be easy to take account; for water at the mean barometrical pressure, and temperature of 68° Fahrenheit, dissolves a volume of carbonic acid equal to itself in bulk; and under the same pressure, and at a temperature of 52°, it dissolves three times its volume of sulphuretted hydrogen. Agitate the water in the jar, therefore, as the case may be, with the proper quantity of either gas, and from the whole quantity which pure water would dissolve, under the same circumstances, deduct that actually absorbed; the difference will indicate the quantity already held in solution by the condensed vapour.

§ 183. *Sulphurous Acid* is very rarely found in mineral waters; but if met with, it must be converted by chlorine into sulphuric acid, precipitated by nitrate of barya, and the sulphate collected, washed, dried, and calcined. 100 parts of this salt represent 27.5 of sulphurous acid by weight: if a water also contain sulphuric acid, or a sulphate, a second portion, to which no chlorine has been added, must likewise be treated with nitrate of barya, and the weight of this precipitate deducted from the former. 100 parts of sulphate of barya contain 34 of sulphuric acid.

§ 184. *Subcarbonate of Ammonia* is as seldom found in mineral waters as sulphurous acid. Its quantity may be ascertained by distilling a portion of the water, condensing the vapour in a receiver containing a little hydrochloric acid, and evaporating the liquid to dryness. The quantity of hydrochlorate of ammonia obtained, will give that of the carbonate: 100 parts of the former indicate 73.5 of the latter.

Separation of the solid ingredients (*a*).

§ 185. Evaporate a sufficient measured quantity of the water, in a tinned copper vessel, 'till it is reduced to about a pint; then transfer the concentrated liquid to a porcelain basin, (taking care to scrape off any solid matter that may adhere to the sides of the copper vessel, and to rinse it with distilled water), and continue the evaporation to dryness. Having thus obtained two or three hundred grains of the residuum, proceed as follows:

§ 186. A. Boil a certain quantity (100 grains for instance), previously well dried at a temperature not exceeding 212°, with seven or eight times its weight of distilled water, for a few minutes, and if turbid, filter the liquid; wash the filter, and dry and weigh the insoluble matter remaining on it.

B. Evaporate the aqueous solution to dryness; weigh the residuum, and digest it in successive portions of alcohol, of the specific gravity of .825, with a gentle heat; filter the liquor, and wash the filter repeatedly with alcohol; evaporate the spirit and dry and weigh the residuum.

The fixed ingredients will thus be separated into three portions. Their nature and the means of separating them, must now be considered.

C. The insoluble portion may contain the carbonates of lime, magnesia, and iron, sulphate of lime and silica. Dissolve the carbonates in a very slight excess

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(*a*) If the water contain a hydro-sulphuret, the mode of operating will be different. (§ 192. C.)

of weak hydrochloric acid, and separate the undissolved portion by the filter. To the filtered liquid add first a considerable excess of acid, and then ammonia to precipitate the oxide of iron, the weight of which, when dried and ignited, will give that of the carbonate of iron. Next add sub-carbonate of soda to the ammoniacal liquor, which will throw down the lime and magnesia in the state of carbonates; they must be collected and washed, converted into sulphates, and separated as mentioned (§ 87); their weights will indicate the quantity of their bases respectively, and consequently that of each of the carbonates.

The sulphate of lime, and the silica, may be separated by sub-carbonate of potassa and hydrochloric acid. The alkali will decompose the sulphate of lime, and the acid dissolve the carbonate which is formed, whilst the silica will remain untouched. The sulphate of lime may then be reproduced, by again separating the earth by sub-carbonate of potassa, or soda, and combining the precipitate with sulphuric acid.

D. The hydrochlorates and nitrates of lime and magnesia, soda, hydrosulphuret of soda, hydrochlorate of ammonia, and common salt, are the only substances, soluble in alcohol, likely to be present in a mineral water; and of the two latter alcohol dissolves but a very small quantity. Soda, which, as well as hydrochlorate of ammonia, is of very rare occurrence in mineral waters, is incompatible with magnesian and calcareous salts, and with hydrochlorate of ammonia; so that it can only be found in the alcoholic solution, associated with the hydrochlorate or hydrosulphuret of soda: consequently, when a mineral water contains no sulphuretted hydrogen, which is always easily known, and is most frequently the case, the portion soluble in alcohol will probably consist only of the hydrochlorates and nitrates of lime and magnesia, and hydrochlorate of soda. Dissolve the salts in water, and add an excess of subcarbonate of ammonia, to precipitate the lime and magnesia, in the state of carbonates, whilst their acids will remain in solution, combined with the ammonia. A small portion of magnesia will probably remain not precipitated; to separate which, add a little phosphoric acid; an immediate precipitation of ammoniaco-magnesian phosphate will ensue. The carbonates and phosphates must be collected *on separate* filters and washed, and the quantities of lime and magnesia of the carbonates ascertained by sulphuric acid (§ 87), and that of the magnesia, contained in the phosphate, by calcination. 100 parts of calcined phosphate of magnesia, contain 40 of magnesia. Next evaporate the liquid containing the common salt, the hydrochlorate, nitrate, and carbonate of ammonia that was added in excess, to dryness, and introduce the residuum into a small retort, from the neck of which a bent tube must pass under, and rise to the top of a receiver full of, and inverted over mercury. Heat the retort gradually; the nitrate of ammonia will be decomposed into water and oxide of azote, and the gas collected in the receiver, and, since as much gas will re-enter the retort on cooling, as was expelled by the heat, what remains in the receiver will exactly represent the quantity of oxide of azote, supposing the temperature and pressure not to have varied during the operation. When the nitrate of ammonia is compleatly decomposed, that is when no more gas is disengaged, the retort must be broken, and the hydrochlorates of soda and ammonia collected. Weigh and calcine them at a low red heat, in a platina or silver crucible, to drive off the volatile salt, whose quantity will be indicated by the weight lost in the operation; which, deducted from the whole weight, leaves that of the common salt. The quantity of acid in the hydrochlorates of lime and magnesia, will then be ascertained from that of the hydrochlorate of ammonia, and the volume of oxide of azote, will give the quantity of the nitric acid (*a*). From these

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(*a*) There is a radical error in this analysis, in the method directed for ascertaining the proportion of the nitrates, by decomposing the nitrate of ammonia by heat. When a mixture of nitrate and hydrochlorate of ammonia, is exposed in a retort to a heat sufficient to decompose the nitrate, a mutual action takes place between the two salts, and a gaseous mixture, containing a large quantity of chlorine, is obtained: as is evident, both from its peculiar odour, from its action on mercury, and from its power to discharge vegetable colours. I have not examined the composition of the gas evolved, but it is clear that the acid of the hydrochlorate must be decomposed, and consequently the process defective. Did its decomposition not take place, it would be difficult to prevent some of the hydrochlorate from being volatilized in the operation.

Perhaps the following scheme may be found more practicable for the analysis of the compound in question.

To the solution of the hydrochlorates and nitrates of lime and magnesia, and hydrochlorate of soda, add cautiously, drop by drop, acetate of silver, 'till no further precipitate ensues, avoiding as much as possible, any excess of the precipitant. The whole of the hydrochloric acid will thus be separated, and there will remain in solution, the acetates of lime, magnesia, and soda, and the nitrates of lime and magnesia. Evaporate to dryness, by a gentle heat, taking care not to decompose the acetates by too high a temperature. Digest the dry mass in rather less than twice its weight of cold alcohol of the specific gravity at least of .850, or better if even .820. This will dissolve the acetates and nitrates of lime and magnesia, and leave the acetate of soda. Decant off the alcoholic solutions, wash the residuum with fresh alcohol, and add the several data, and from the quantities of lime and magnesia, which are already known, it will not be difficult to estimate the respective proportions of the calcareous and magnesian hydrochlorates and nitrates.

100 parts of nitric acid saturate	52.5	lime
. . . .	36.5	magnesia
100 parts of hydrochloric acid saturate	102.	lime
. . . .	72.3	magnesia

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washings to the decanted portion. The acetate of soda may then be converted into subcarbonate by a red heat, and weighed.

Distill off the alcohol from the dissolved salts, redissolve them in water, and to the solution add subcarbonate of potassa, avoiding unnecessary excess: this will throw down the lime and magnesia in the state of carbonates, and leave in solution acetate and nitrate of potassa and a small portion of carbonate of potassa. Separate the precipitate, evaporate the solution again to dryness, and boil the residuum in alcohol of .820, which will dissolve the acetate of potassa, and leave the nitrate and sub-carbonate. Separate the spirituous solution, and distill it to dryness, and convert the sub-carbonate of potassa into acetate, by pure weak acetous acid. A repetition of the action of alcohol, of the same specific gravity as the former, will then separate the acetate, and the nitrate of potassa will be left insulated. By the first process we get chloride of silver, from whence the whole quantity of hydrochloric acid is obtained; by the second sub-carbonate of soda, which denotes the quantity of acid in the hydrochlorate of soda: by the third, the carbonates of lime and magnesia, whence we learn the weight of those bases; and from the weight of the nitrate of potassa of the last process, we find the quantity of nitric acid. From these data the proportions of the several salts in the mixture may be estimated.

100 chloride of silver, are equivalent to	25.46	hydrochloric acid
100 nitrate of potassa - - -	52.88	nitric acid
100 subcarbonate of soda - -	110.	common salt
or - -	68.7	hydrochloric acid
100 carbonate of lime - - -	56.	lime
100 - - magnesia - -	47.	magnesia

The quantities of lime and magnesia, which saturate equal portions of hydrochloric and nitric acids, are given above.

100 parts of hydrochlorate of ammonia, contain 51 hydrochloric acid; 100 cubic inches of oxide of azote weigh 46.125 grains; and 100 parts by weight, of the oxide, indicate 123.17 parts of nitric acid.

Instead of treating the whole solution (after the separation of the lime and magnesia, by sub-carbonate of ammonia) in the manner just mentioned, a moiety of it may be submitted to a different process, as follows:

Digest the solution, freed from the carbonate of ammonia by boiling, on phosphate of silver in excess: chloride of silver, and phosphates of soda and ammonia will be formed. The two last salts will remain in solution, with the nitrate of ammonia; but the chloride of silver, with the excess of phosphate of silver fall down.

Nitric acid will take up the latter, and leave the chloride, whose weight may then be ascertained. Next pour sub-carbonate of soda into the filtered liquor, in order to convert the phosphate and nitrate of ammonia, into phosphate and nitrate of soda; then evaporate to dryness, and heat the residuum with alcohol of the specific gravity of 0.850, which will dissolve the nitrate of soda, but have no action on the other salts. The quantity of dry nitrate of soda, will give that of the nitric acid, and the quantity of chloride of silver, that of the hydrochloric acid of the hydrochlorates of soda, lime and magnesia; and since the quantity of common salt, and consequently that of its acid, is already known by the first process, deducting the latter from the whole quantity of hydrochloric acid, the quantity of the acid of the hydrochlorates of lime and magnesia, is obtained.

By thus varying the processes, the quantities of the nitric and hydrochloric acids are obtained in different ways, and the results, if they harmonize, entitled to the greater confidence.

§ 187. The substances soluble in water only, are more numerous than the preceding; they amount to 13, namely; the sulphates of soda, magnesia, ammonia, iron and copper, and alum; nitrate of potassa, the hydrochlorates of potassa and soda; the sub-borate of soda and boracic acid. (*a*)

§ 188. The sulphates of magnesia, ammonia, iron, and copper, and the hydrochlorates and carbonates of potassa and soda are known by the characters already described, (§ 178.) Sulphate of soda, nitrate of potassa, boracic acid, and alum, by solution in water and crystallization, (*b*) and borax by sulphuric acid precipitating boracic acid, from a concentrated solution of that salt.

§ 189. The sulphates of ammonia, iron and copper, alum, nitrate, hydrochlorate and carbonate of potassa, borax and boracic acid, are very rarely found in mineral waters, and carbonate of soda or potassa,

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(*a*) Although common salt has been classed with the substances soluble in alcohol it is necessary to place it also with those insoluble in that agent, which takes up so small a portion that it commonly makes part of both classes.

(*b*) Nitrate of potassa is distinguished from all the rest by scintillating when thrown on red hot charcoal; boracic acid by the beautiful green colour it imparts to the flame of burning alcohol; and alum, by ammonia throwing down its alumina. The form of the crystals of sulphate of soda is a six-sided prism, with dihedral summits; that of nitre, a six-sided prism, terminated by six-sided pyramids. Boracic acid crystallizes in thin hexagonal plates, and alum in regular octohedra.

is incompatible with sulphate of copper and free boracic acid. Thus the sulphates of soda and magnesia, common salt and carbonate of soda, are almost the only substances of this class likely to be met with; moreover, only three of them can exist together, for sulphate of magnesia and carbonate of soda mutually decompose each other.

§ 190. Suppose, first, there be no sulphate of magnesia in the water; treat the mixture with successive portions of alcohol of the specific gravity of 0.875, which will dissolve all the common salt; then, adding acetic acid to the sulphate and carbonate of soda, the latter will be converted into an acetate, soluble in alcohol, and thus easily separated from the sulphate;—the quantity of acetate will give that of the carbonate.

§ 191. Secondly, suppose there be no carbonate of soda present; the sea salt is to be separated, as before, by alcohol; then dissolve the residuum in water and add hydrochlorate of barya till it produces no further precipitate, taking great care not to add it in excess. The sulphates of soda and magnesia will be decomposed, insoluble sulphate of barya will fall down, and the hydrochlorates of soda and magnesia remain in solution. Evaporate the liquid to dryness, and calcine the residuum in a platina crucible at a red heat. The hydrochlorate of magnesia will thus be deprived of its acid, and the common salt may be separated from the magnesia by water. 100 parts of common salt are equivalent to 53.25 of soda. From the quantities of soda and magnesia, the quantities of their sulphates may be estimated, and the weight of the sulphuric acid from that of the sulphate of barya.

§ 192. If a mineral water contain a hydrosulphuret, (*a*)

A. Collect the gases, as stated, (§ 180.)

B. The carbonates of lime and magnesia, the sulphate of lime, and the silica must also be separated by the usual methods, except that it is better to evaporate the water in a retort than in a basin, to prevent the action of the air on the hydrosulphuret.

C. To ascertain the quantity of the hydrosulphuret (or, more properly, sulphuretted hydrosulphuret) introduce the water into a tubulated retort, having a tube of safety fitted to the tubulure, and a common tube to its neck, which must pass into a flask containing acetate of lead; pour acetic acid into the water through the tube of safety, and heat it gradually till it boils. The hydrosulphuret will be decomposed; its sulphuretted hydrogen will pass into the flask and produce sulphuret of lead, and the sulphur that was united with the hydrosulphuret will be precipitated.—From the weight of the sulphuret we obtain that of the sulphuretted hydrogen, and from the weight of the latter and the sulphur, that of the sulphuretted hydro-sulphuret. (*b*) (*c*)—100 of lead combine with 15.5 of sulphur, and 15 of sulphur with 1 of hydrogen. The sulphuretted hydrosulphurets (hydrogu-

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(*a*) The hydrosulphuret is never pure, it is always more or less sulphuretted.

(*b*) It would be better, and it is sometimes possible, to determine the quantity of the base of the sulphuretted hydro-sulphuret in a direct manner, than to deduce it from the weight of the sulphuretted hydrogen and the sulphur, particularly as the latter is difficult to collect.

(*c*) This process supposes the water to contain no free sulphuretted hydrogen; if that be the case, which will be known by its smell, it must first be driven off by a gentle heat.

retted sulphurets) are probably formed of two atoms of sulphur, one of hydrogen, and one of base; thus, if it be the sulphuretted hydrosulphuret of soda, (or more properly of sodium,) its composition would be sodium 22, sulphur 30, hydrogen 1=53.

D. The quantity of carbonate of soda may be determined by a similar process. After boiling the water, to throw down the insoluble carbonates, filter and treat it with hydrochloric acid, in an apparatus like that mentioned § 181, containing a solution of ammonia and hydrochlorate of lime, in the manner there directed; from the weight of the carbonate of lime that of the alkaline salt will be deduced.—100 parts of carbonate of lime are equivalent to 105.5 parts of sub-carbonate of soda, deprived of its water by a red heat, and to 168 parts of the crystallized bi-carbonate.

E. It remains to consider how the other substances are to be separated. If carbonate of soda be present the water can contain besides, only the carbonates of lime and magnesia, silica, hydrosulphuret of soda, and other salts with base of that alkali. In that case add an excess of acetic acid and evaporate to dryness; calcine the residuum at a red heat, affuse water on it, and filter the liquor. The soda of the carbonate and hydrosulphuret, and the other salts (generally only sulphate and hydrochlorate of soda) will be dissolved.

To the solution add sub-carbonate of ammonia to convert the soda completely into sub-carbonate, and boil the liquid to drive off the excess of the volatile carbonate, and then proceed to ascertain the quantities of sea salt and sulphate of soda, by alcohol and acetic acid, as directed, (§ 190.) At the same time the quantity of acetate must be ascertained, which will give that of the soda, and the quantities of carbonic acid and sulphuretted hydrogen those of the hydro-sulphuret and sub-carbonate.

F. If no carbonate of soda be present, a mineral water may contain, in addition to the substances mentioned in the last paragraph, the sulphates, hydrochlorates and nitrates of lime and magnesia. In this case, agitate it with an excess of chloride of mercury (calomel) which will decompose the hydrosulphuret and an insoluble black sulphuret of mercury, and hydrochlorate of lime or soda, according as the sulphuretted hydrogen was united to one or other of those two bases, will be formed. To complete the analysis, observe the directions contained in the sections 185, et seq.; but, from the quantity of hydrochlorate obtained, must be deducted that which arises from the action of the hydrosulphuret on the chloride of mercury. For this purpose, take a fresh portion of the water, add nitric acid, and boil it to expel the sulphuretted hydrogen; then filter and drop in an excess of sulphate of silver. (*a*) The weight of the chloride of silver that will be formed will indicate the real quantity of the acid contained in the water, whence that arising from the calomel may be estimated. Since the sum of the two quantities has been given by the first experiment, and the quantity of acid derived from the chloride is also known, the quantity of base which saturates it is likewise obtained. The quantity of hydrosulphuret will likewise be found from the same data, as it is the result of the union of that base with the sulphuretted hydrogen.

(*a*) As a sulphate may be present this is preferable to nitrate of silver.

§ 193. In all cases it is right in the first instance to devote a portion of the water to an inquiry into the nature of its contents before the more perfect analysis is undertaken.

Most chemists have had occasion to employ themselves in the analysis of mineral waters, but Bergman and Kirwan alone have given general dissertations on the subject. The work of the former is of the date of 1778, and Kirwan's, of 1799. Both deserve praise. The reader will find the method of analysis adopted by Kirwan in the third volume of Dr. Thomson's System of Chemistry, fifth edition, in which and in Dr. Henry's Elements of Experimental Chemistry much useful information on the subject is contained. Saunders's Treatise on Mineral Waters and the work of M. Bouillon Lagrange, on natural and artificial mineral waters, published in 1810, may also be consulted with advantage.

In addition to the preceding directions of my author, an example of the actual analysis of a mineral water, cannot fail to be extremely useful to the student in this intricate and difficult part of our subject. And I know none better calculated for the purpose than the ingenious and accurate one of the celebrated Bath water, by my friend Mr. Richard Phillips, in which it will be seen how attentively the phenomena produced by the different re-agents must be observed, and how cautiously the inferences they appear to lead to, adopted.

Analysis of the Hot Springs at Bath, by Mr. R. Phillips.

The nature of the country round Bath, and other local circumstances, have been so fully described by those who have given chemical examinations of the waters of the hot springs at that place, that any further description appears unnecessary.

As to the cause of the heat of these springs, we have so few data from which to reason, that I shall not offer even a conjecture on the subject.

These waters have been frequently analysed. They have merited the attention they have received, not only from their early and extensive employment in the cure of diseases, but also on account of some peculiar changes to which they are subject. Of these the explanations have been so various as to show that they require still further examination.

Of the sensible properties exhibited by these waters the most remarkable is their high temperature, the degree of which varies considerably at their different sources. At the hot bath it is 117°; at the king's bath 114°; and at the cross bath 109°. This statement does not exactly agree with what has been usually given as their temperature. These results were obtained by pumping the water upon the bulb of a thermometer till the mercury ceased to rise. Their taste is metallic, but not strongly or disagreeably so; this has not been universally allowed: but if they are drank hot, this impression is readily distinguishable.

Their specific gravity is 1.002 at each of the springs; and as the effects produced by chemical tests are also perfectly similar, they may be considered as derived from one source, the temperature varying by their more or less circuitous passage to the surface. For the purpose of analysis the water of the king's bath has been usually employed; and although, it does not appear to be a matter of much importance, I have followed the usual practice.

Before the experiments made upon the water are related, it will be necessary to state those employed to ascertain the properties of the gas, which rises in great quantity through the water in the king's bath.

This gas is perfectly free from smell.

A. Some of the gas was received into a jar. A lighted taper put into it was immediately extinguished.

B. Received into lime water, it caused an immediate precipitation.

C. Tincture of litmus suffered no change of colour by agitation with the gas.

D. The colour of dilute tincture of turmeric and tincture of galls was destroyed by it.

From these effects the gas appears to consist principally of azotic gas with a small portion of carbonic acid gas. To ascertain the quantity of each, and whether any oxygen gas was present, the following experiments were performed:

E. One hundred measures of the gas were strongly agitated with barytes water in a graduated tube. A considerable precipitate was deposited, and five measures were absorbed.

F. One measure of deutoxide of azote was added to an equal quantity of the gas in an eudiometer in the water apparatus. The mixed gases underwent no alteration of colour nor diminution of volume.

G. One hundred measures of the gas which had been deprived of carbonic acid by barytes water were submitted to the action of solution of protomuriate of iron impregnated with deutoxide of azote. No absorption took place.

This gas, therefore, consists of,

Carbonic acid gas	5
Azotic gas	95
	100

I now proceeded to try whether the water held either of these gases in solution.

H. Ten ounces of the water which had been cooled in a well-closed bottle, were put into a vessel furnished with a bent tube; the water was boiled for about twenty minutes, and the gas evolved from the water and the air of the tube, except a quantity too small to be estimated, were received in a graduated jar over mercury. Solution of potash absorbed three-fourths of an inch of this gas, which was carbonic acid.

I. The unabsorbed gas was transferred to the water apparatus, and tried in the usual way with deutoxide of azote. The mean result of comparative experiments upon it and atmospheric air, showed that it was merely the air of the vessel, and that no azotic gas was held in solution by the water.

As ten ounces of the water gave ·75 of an inch of carbonic acid, one quart would furnish 2.4. This quantity is not quite exact, it being scarcely possible to obtain the whole of the carbonic acid by ebullition.

Effects of Atmospheric Air and Re-agents.

K. Some of the water, while hot, having been exposed in a vessel of broad surface to the atmosphere, afforded in a few hours a small quantity of a white precipitate; but water which had been cooled in a close vessel remained perfectly transparent after several weeks exposure to the air.

The re-agents added to the water while hot, and the effects produced by them were the following:

L. Acetate of lead,—a perfectly white precipitate.

M. Tincture of litmus,—no alteration of colour.

N. Tincture of turmeric,—no change indicating the presence of uncombined alkali; its colour immediately destroyed.

O. Lime water,—a white precipitate.

P. Potash,—a white precipitate.

Q. Carbonate of potash,—a white precipitate.

R. Some of the water was boiled with a little nitric acid,—potash added to this gave no precipitate.

S. Oxalate of ammonia,—a precipitate.

T. Nitrate of barytes, a precipitate insoluble in nitric acid.

U. Nitrate of silver,—a white precipitate insoluble in nitric acid.

V. Solution of sulphuretted hydrogen,—no precipitate nor change of colour; the water became very slightly turbid.

W. Prussiate of potash,—no immediate effect: after some weeks the water became slightly green.

X. Tincture of galls,—immediately a peach-blossom red colour, and very soon a precipitate which became dark purple by exposure to the air.

All the above effects are also produced after the water has been cooled, excepting that the colour of tincture of turmeric is not then destroyed, and, under some circumstances, no red colour occurs upon the addition of tincture of galls.

Y. A quantity of the water was evaporated to dryness, and distilled water added to the residuum. Nitrate of lime poured into the solution afforded a crystalline precipitate in a few hours, indicating the presence of an alkaline sulphate.

I shall now state the inferences to be deduced from these experiments.

Carbonic acid exists in this water (BE). A considerable portion of it escapes at the high temperature at which the water is obtained, its evolution occasioning the precipitation of some substance which it held in solution (K).

From Experiment (L) it is evident that no sulphuretted hydrogen gas is present.

As no alteration of colour is effected upon tincture of litmus by the carbonic acid (M), it is evident that this acid is present only in sufficient quantity to dissolve the substance precipitated by its evolution.

The destruction of the colour of tincture of turmeric (N) is clearly occasioned by the gas during its passage through the water (D).

The effect produced in experiment (O) is owing to the formation of carbonate of lime, and the precipitation of it and of the substance previously dissolved by carbonic acid (K).

A part of the precipitate obtained by adding potash (P) must have been similar to that of experiment (K), and to a portion of that of experiment (O), produced in (P) and (O) by combining the solvent carbonic acid instead of expelling it as in experiment (K). The precipitate was carbonate of lime, or of magnesia, or both.

As earthy carbonates are not precipitable by alkaline carbonates, the precipitate formed by carbonate of potash (Q) indicates the presence of some other earthy salt.

From experiment (R) it appears that no alumina nor magnesia exists in the water, and that the precipitate obtained in experiment (K) was carbonate of lime.

Experiment (S) determines the presence of lime.

Experiment (T) shows that sulphuric acid exists in the water.

The effect, produced by nitrate of silver (U) results from the action of muriatic acid.

As no metallic oxide discoverable by sulphuretted hydrogen, was suspected, the appearance it produced (V) was supposed to be derived from its action upon carbonate of lime. This was ascertained to be the case by direct experiment.

As the prussiate of potash employed in experiment (W) contains oxide of iron as one of its consituents, it was imagined that the slight greenness which was assumed by the water might be occasioned by the action of the carbonic acid, notwithstanding its holding carbonate of lime in solution, this effect being easily produced by the application of the stronger acids. A small quantity of the triple prussiate was therefore added to a solution of carbonate of lime in carbonic acid: after a considerable time it acquired a green colour exactly similar to that observed in experiment (W). Dr. Falconer has indeed stated that a blue colour is to be obtained by the action of prussiate of potash upon the water; but, as it did not occur till after the addition of sulphuric acid, it is evident that this effect was produced by the action of the acid upon the oxide of iron of the prussiate.

Although the presence of oxide of iron is not at all indicated by prussiate of potash, (probably on account of the smallness of its quantity,) yet it is evident from the action of tincture of galls (X) that a minute portion of it actually exists in the water; the light colour of the recent precipitate, and its becoming darker by contact with atmospheric air, showing that it is in the state of protoxide. In making this experiment it is requisite to use a very small quantity of the tincture of galls; for, if much more than five drops of it are added to one ounce of the water, no indication of oxide of iron is produced, the water becoming of a light reddish brown colour, and affording no precipitate. An excess of this tincture re-acts upon the compound of vegetable matter and oxide of iron so completely as to prevent the appearances readily presented by a small quantity.

From the well-known laws of chemical affinity it is evident that the oxide of iron is combined with carbonic acid; this compound undergoing some curious changes, which have occasioned much discussion.

It has been observed, that one of the most active tests of oxide of iron does not in this water produce any appearance of its presence; and the slight metallic taste which it communicates when hot and fresh has been unnoticed by some analysts. This taste is lost by cooling, even in well-stopped bottles; and every method which I have tried to restore it has been unsuccessful. It has also been mentioned that the action of tincture of galls is in some cases lost; and this fact has occasioned most discussion respecting the oxide of iron. The following experiments will show under what circumstances this occurs.

a. About one pint of the water was exposed, while hot, to the atmosphere in a vessel of broad surface.—After it had remained about 16 hours, a small quantity of carbonate of lime was deposited by the evolution of carbonic acid gas. The precipitate was perfectly white, and had not the slightest appearance of containing oxide of iron. To this water tincture of galls was added without occasioning the least alteration of colour.

b As the quantity of oxide of iron in the water is evidently extremely small, it may be imagined that it was precipitated with the carbonate of lime, but escaped observation from the minuteness of the quantity. To obviate this objection, some of the water was closely stopped in a vial for four or five days: upon examination it was found to possess its transparency perfectly, and without having afforded any precipitate; to some of this, tincture of galls was added without producing the slightest indication of oxide of iron.

c. Some of the water which had been cooled so as to retain its transparency, was heated to its original temperature; tincture of galls was then added, but without producing any effect.

The facts exhibited in experiments (*b*) and (*c*) have been long known, and have given rise to an idea that the iron is volatilized. Although this opinion is incompatible with facts already mentioned, yet it may not be amiss to show more particularly that it is completely erroneous. As it cannot be imagined that the temperature of the water is sufficient to volatilize mere oxide of iron, the existence of some substance capable of carrying it off must have been supposed.—That muriatic acid and muriate of ammonia possess this power at high temperatures is well known, but no muriate of ammonia is present, nor is any muriatic acid except in combination. Hydrogen gas is said also to be capable of volatilizing iron; but the gas evolved from the water has been shown to consist of azotic gas and a small quantity of carbonic acid gas; and to these gases, either separate or combined, no such power has ever been attributed. If, however, they really possess it in this instance, they must be regarded as the solvent of the iron, and the effect produced upon tincture of galls must be derived from the gas diffused in small quantity through the water. If this be the case, the application of the concentrated solution of iron should produce a much more distinct effect upon the tincture; but it has been shown (D) that the gas destroys the colour of tincture of galls instead of increasing it, which would be the effect if it contained oxide of iron.

d. About one gallon of the water was put into a vessel of considerable depth, of which it occupied about two-thirds: it was slightly covered, and remained about twenty-four hours. It then retained its power of affording a peach-blossom coloured precipitate with tincture of galls (X) in a very considerable degree.

It is remarkable that in this experiment the result should have proved so different from that obtained in one where the circumstances were similar, excepting only the form of the vessel and the quantity of the water. When the water was exposed with a broad surface, tincure of galls shewed no action on it (*a*);

but in this case, even after eight hours longer exposure, it detected oxide of iron.

From this circumstance I began to suspect that some change was produced by the absorption of oxygen, and that it had not produced the same effect in this as in the former experiment, on account of the quantity of the water and depth of the vessel. There appeared, however, a strong fact against this supposition; viz. that iron is more easily detected when highly oxidized, whereas the contrary effect was in this case produced.

To try the effect of atmosphere air, the following experiments were performed:

e. A small quantity of the water was enclosed, while hot, in a well-stopped vial, with about one-fortieth of its volume of atmospheric air. After four days the water remained perfectly transparent, but the addition of tincture of galls did not afford the slightest appearance of its containing iron.

f. Another portion of the water was kept for the same length of time in a well-stopped vial, but without any air except such as the water held in solution. Tincture of galls occasioned exactly the same appearance of iron in this as in the water when fresh and hot (X).

That the action of tincture of galls is lost by the absorption of the oxygen of atmospheric air is proved by the following experiment:

g. A third quantity of the water was enclosed, with the usual precaution, in a vial, about one half of which was occupied by the gas evolved from the water in the bath, which has been shewn to contain no oxygen gas. After four days, tincture of galls was added to it, and gave the same appearances of oxide of iron as occur in its application to the fresh hot water.

Having thus ascertained the effect of oxygen in preventing the action of tincture of galls upon oxide of iron, it remained to be shown in what manner this is effected. I imagined it might be produced by increasing the power of combination of the oxide of iron so as to admit of its acting upon the earthy contents of the water and forming compounds, the strong affinity of the constituents of which prevented the action of the tincture of galls. With a view to ascertain how far this supposition was correct, I examined the effects produced by adding carbonate of lime, dissolved by carbonic acid, to solution of sulphate of iron to which tincture of galls had been previously added; and although it will appear, by the following experiments, that the alterations produced upon the oxide of iron in the water are caused by the carbonate of lime it contains, it will also be found that they are not effected in the way I had supposed.

A very dilute solution of proto-sulphate of iron was prepared: the quantity of oxide of iron contained in it was so small as scarcely to afford any alteration of colour when tincture of galls was added to it; but upon pouring solution of carbonate of lime into it after tincture of galls had been added, a deep red colour was almost instantaneously produced.

Although this fact did not immediately appear likely to solve the difficulties attendant upon the water in question, yet it was sufficiently striking to merit an examination by what means the carbonate of lime produced this effect, and to what extent it might be employed in rendering tincture of galls a more active reagent.

With this intention I boiled some crystallized sulphate of iron in alcohol till nearly the whole of the per-sulphate was separated. The remaining quantity being extremely small, I shall consider the iron in this solution as entirely in the state of protoxide. The sulphate, insoluble in alcohol, was dissolved in water, and the quantity of the oxide contained in a given portion of the solution was ascertained by taking the average of two experiments.

h. To one ounce of this solution, containing about $\frac{1}{100}$dth of a grain of protoxide of iron, tincture of galls was added. This occasioned the usual appearance indicated by the presence of oxide of iron in a very slight degree. The colour produced, increased by the absorption of the oxygen of the atmosphere.

i. An equal quantity of the solution was treated with prussiate of potash. A light blue colour was immediately produced by the minute portion of peroxide of iron which had escaped the action of the alcohol: the intensity of this colour gradually increased by the action of atmospheric air till the iron was totally converted into peroxide.

k. Tincture of galls was added to one ounce of a dilute solution of carbonate of lime containing about $\frac{1}{100}$dth of a grain of oxide, as in the former experiments. A red purple colour, of very considerable intensity, was immediately produced.

l. The last experiment was repeated, employing only about $\frac{1}{1000}$dth of a grain of oxide, instead of $\frac{1}{100}$dth. A very distinct red purple was immediately produced by the action of the tincture of galls.

m. To one ounce of a solution of carbonate of lime, containing $\frac{1}{600}$dth of a grain of oxide of iron, prussiate of potash was added; but it did not produce any indication of having acted upon the oxide of iron.

I now prepared a solution of persulphate of iron by treating the protosulphate with nitric acid in a red heat. The quantity of oxide which the solution contained was as in the former case ascertained. The experiments made with this were as follow:

n. One ounce of a solution of persulphate of iron, containing $\frac{1}{1000}$dth of a grain of oxide, was treated with tincture of galls. The usual indications of its action upon oxide of iron were presented.

o. The addition of prussiate of potash to an equal quantity of the solution immediately occasioned a blue colour.

p. Tincture of galls was added to one ounce of a dilute solution of carbonate of lime containing $\frac{1}{1000}$dth of a grain of the peroxide of iron. Slight indications of its action upon the oxide were produced, but the colour was scarcely more intense than that effected by $\frac{1}{6000}$dth of a grain of protoxide in similar circumstances: no effect whatever was produced by infusion of galls upon $\frac{1}{10000}$dth of a grain of peroxide in one ounce of solution of carbonate of lime. The colour produced when carbonate of lime and tincture of galls are added to the peroxide is reddish purple, similar to that occasioned by their action upon the protoxide.

q. To one ounce of a solution of carbonate of lime, containing, as in the last experiment, $\frac{1}{1000}$dth of a grain of peroxide of iron, prussiate of potash was added. Not the slightest blue colour was produced. When carbonate of lime was thus added to the solution of peroxide of iron, I found that it was capable of preventing the action of prussiate of potash upon $\frac{1}{250}$th of a grain.

From these experiments it is evident that carbonate of lime possesses, in a very great degree, the power of increasing the action of tincture of galls upon protoxide of iron; while, on the contrary, it diminishes its power in detecting peroxide of iron; and is, moreover, capable of preventing the action of prussiate of potash, to a certain extent.

The application of these experiments to the circumstances of the water in question is obvious. It has been shewn that it contains carbonate of lime; and that the power of tincture of galls to detect the oxide of iron it contains is completely lost by the absorption of oxygen. The following experiment was made with the intention of trying whether this effect of slow oxidizement might be imitated.

r. Tincture of galls is, as has been seen, capable of acting upon $\frac{1}{6000}$dth of a grain of protoxide of iron in one ounce of solution of carbonate of lime (*l*). A portion of sulphate of iron containing $\frac{1}{6000}$dth of a grain of protoxide was dissolved in one ounce of dilute solution of carbonate of lime, and was kept in contact with about one-fourth of its volume of atmospheric air, during twenty-four hours. At the end of that time the solution remained perfectly transparent, nor had any precipitation occurred in it. But the addition of tincture of galls did not occasion the slightest appearance of having acted upon the oxide of iron. In this experiment the loss of power of tincture of galls is much more speedily effected than in the Bath water. This is evidently owing to the atmospheric air contained in the distilled water employed, whereas no oxygen gas is present in the Bath water.

When carbonate of lime is added to sulphate of iron it is well known that double decomposition takes place, the iron being thus combined with the carbonic acid instead of the sulphuric. Having found that tincture of galls, in several instances, acts much more readily upon carbonates than sulphates, I imagined that the carbonate of lime produced its effect in this way. To ascertain whether this supposition was correct I made the following experiment:

s. A quantity of the solution of protosulphate of iron, similar to that employed in the above-related experiments, was decomposed by carbonate of potash; carbonic acid gas was passed through water in which the washed carbonate of iron was diffused, and to some of the filtered solution tincture of galls was added; but, instead of the reddish purple colour effected by the action of carbonate of lime upon sulphate of iron and tincture of galls (*k*) and (*l*), the usual deep blue colour was produced.

t. One-tenth of the quantity of carbonate of iron employed in the last experiment was dissolved in a solution of carbonate of lime equal in measure to the last solution. To this, tincture of galls was added. The reddish purple colour was immediately produced, and from its intensity it was evident that carbonate of lime had increased the power of tincture of galls as much in employing the carbonate as the sulphate of iron.

It may be concluded, from these experiments, that the effects produced by carbonate of lime are not attributable to the conversion of the sulphate of iron into a carbonate; and I have found that alkalies and their carbonates possess the peculiar power of increasing the mutual affinity and action between tincture of galls and protoxide of iron.

I next examined the salts produced by evaporating the water and crystallization.

u. A quantity of the water was evaporated to dryness: the residuum was treated with distilled water as long as that fluid continued to dissolve any portion of it. This solution was again evaporated, and upon cooling yielded a considerable quantity of acicular crystals. These were again dissolved in distilled water; and to a part of the solution nitrate of barytes was added, which occasioned a copious precipitate. The same effect was produced by oxalate of ammonia; but ammonia caused no precipitation. These crystals were therefore sulphate of lime. By further evaporation the solution afforded cubic crystals of common salt and prismatic crystals of sulphate of soda.

The next object to be attained was the weight of the total quantity of the various substances held in solution by a given portion of the water. This has been given with considerable variation, by different analysts, as will appear by the following statement. From a quart of the water

Dr. Lucas obtained	33½ grains of dry residuum.
Dr. Charlton . .	34
Dr. Falconer . .	17¼
Dr. Gibbes . .	23¼

To account for the great difference of these results, Dr. Saunders has supposed that the water varies at different times, or that the residuum has been dried with various degrees of heat. I have ascertained the quantity of the contents of the water several times during about eighteen months, without observing any other variation in its weight than is unavoidable in experiment. In support of this observation it may be remarked, that I found its specific gravity exactly as stated by Dr. Falconer.

It is scarcely probable that the results of any of these analyses were obtained by drying the residuum at a lower temperature than 212°, or at a greater than a red heat. Now I find that one quart of the water, weighing 30 troy ounces 172 grains, at the temperature of 63°, gives 32 grains of residuum dried at 212°: when the heat of a sand-bath is employed, 30 grains are obtained; and at a red heat, 28 grains. The greatest variation afforded by these methods is four grains; whereas from some cause, which it is difficult to explain, the extreme difference of the experiments above cited is 16¼ grains. When a red heat is employed, a part of the loss is occasioned by the decomposition of the carbonate of lime; for water poured upon the residuum turns turmeric paper of a reddish brown colour. The greater part of the residuum is perfectly white; the portion deposited at the upper part of the vessel is, however, slightly greyish, but not at all appearing as if coloured by oxide of iron. I suspected that it might be occasioned by carbonaceous matter: to ascertain whether this was the case, the following experiment was made:

v. Four pints of the water were evaporated to dryness in a retort, and the residuum boiled with about five ounces of alcohol. The filtered solution left, on evaporation, 8.3 grains of a yellowish coloured subsubstance. A part of this was dissolved in water, and afforded a copious white precipitate with nitrate of silver, but did not give any with ammonia or with carbonate of ammonia: common salt was therefore the only one dissolved by the alcohol.

w. To the remaining portion of the saline mass colourless sulphuric acid was added. By heating, the acid acquired a dark brown colour, evidently derived from its action upon carbonaceous matter. This experiment did not appear conclusive, as two causes of error might have existed,—a small quantity of alcohol was probably decomposed by the action of the salts upon it, or some of the conferva which is found in the water might have escaped notice previous to evaporation. I had recourse, therefore, to other means. Mr. Kirwan, in his Treatise on the Analysis of Mineral Waters, gives a method for ascertaining the presence and quantity of extractive matter proposed by Westrumb, which consists in precipitating the muriatic salts by nitrate of lead, and afterwards the extractive matter by nitrate of silver. It is impossible to conceive any method more completely fallacious than this; for extractive matter is as readily precipitated by nitrate of lead as by nitrate of silver; and although common salt is decomposed by nitrate of lead, muriate of lead being a salt of considerable solubility, the subsequent addition of nitrate of silver would decompose it, and afford a precipitate consisting of muriate of silver without any extractive matter.

The power of sulphuric acid in detecting carbonaceous matter is extremely great: $\frac{1}{100}$dth of a grain of sugar was dissolved in four ounces of water; to this solution about one ounce of sulphuric acid was added: it was then boiled till nearly the whole of the water was evaporated, and the acid had acquired a very distinct brown colour.

The following experiment was now made:

x. A quantity of sulphuric acid was added to one quart of the water perfectly transparent, and free from heterogeneous matter. The mixture was evaporated nearly to dryness in a retort, and the sulphuric acid remained perfectly colourless. The water, therefore, contains no carbonaceous matter.

The substances contained in the water, as shown by the foregoing experiments, are; carbonate of lime, oxide of iron, sulphate of lime, common salt, and sulphate of soda. The presence of these compounds has been universally allowed; but that silica is contained in the water, was discovered by Dr. Gibbes. To find the quantity of each of these, the following methods were employed:

y. A quart of the water was evaporated to dryness in a platina crucible: the residuum, dried in a sand heat, weighed thirty grains. This was boiled, with successive portions of distilled water, till it ceased to afford a precipitate with nitrate of barytes. The solution was then divided into three equal quantities.

z. To one of these portions nitrate of silver was added as long as precipitation took place, and distilled water was poured upon the precipitate till it came away quite pure. The chloride of silver thus obtained was weighed after exsiccation.

A. The second quantity was treated with oxalate of ammonia while it continued to produce any effect. The precipitated oxalate of lime was washed, dried, and weighed.

B. To the remaining part of the solution nitrate of barytes was added till it ceased to produce any precipitate; and the sulphate of barytes obtained by its action was weighed, after washing and drying, as in the former experiments.

C. The residuum, insoluble in water, weighed, when dried, two grains: nitric acid added to it dissolved 1.7 grains. This solution afforded no precipitate with potash, but a copious one with oxalate of ammonia:

it was therefore nitrate of lime obtained by the decomposition of the carbonate.

D. The 0·3 of a grain left by the nitric acid was dissolved by potash, and precipitated from it by muriate of ammonia. This precipitate was not again soluble in nitric acid, and was consequently silica.

Another quart of the water was treated in the same way. To avoid prolixity, I shall state the quantity of each precipitate afforded by one-third of a quart multiplied by three, and make the requisite calculations from the mean of the two experiments.

	Exp. I.	Exp. II.	Mean
Residuum . . .	30·	30·	30· grains
Chloride of silver	16·2	16·2	16·2
Oxalate of lime .	18.3	17.7	18·
Sulphate of barytes	36·6	36·9	36·7
Carbonate of lime	1·7	1·5	1·6
Silica	0·3	0·4	0·35

According to Dr. Gibbes, a quart of the water affords nearly 4 grains of silica when treated in the method I have described. Thinking it probable that a portion of it might be taken up by the action of the salts during their solution in water, I tried whether any larger quantity could be obtained by the following method:

E. A quart of the water was evaporated to dryness in a platina crucible. The residuum was repeatedly treated with nitric acid in a red heat; the soluble parts were again redissolved in distilled water, and the portion insoluble in it, when dried, weighed 0.4 of a grain. This agreeing exactly with the last experiment, I shall consider it as the quantity of silica afforded by a quart of the water. This experiment was several times repeated, with very little variation in the weight of the result, but was sometimes evidently coloured by oxide of iron, which was separated from the silica, and its nature ascertained by the usual means.

To find the quantity of oxide of iron contained in the water, the following means were employed:

F. To a quantity of the hot water tincture of galls was added in the requisite proportion. The water measured when cold 9½ pints. The precipitate obtained was separated by the filter, and dried: the precipitate and filter were then burned together in a platina crucible, and the carbonaceous matter of the filter, and that combined with the iron, were dissipated by the application of a red heat. The residuum was then treated with nitric acid, in order completely to oxidize the iron: it was then boiled with acetic acid to take up the lime precipitated with the oxide of iron by the tincture of galls; and afterwards with potash, to dissolve any silica which the filter might have furnished: the remaining substance was evidently peroxide of iron, and weighed 0.2 of a grain.

G. The last experiment was repeated, slightly varying the method. Tincture of galls was added, as before, to a quantity of the hot water, measuring after it had cooled 17¼ pints. The precipitate was suffered to subside, and the water poured off until only a small quantity remained. This was evaporated, and the residuum, treated with nitric acid in a red heat, weighed 0.5 of a grain. Being exposed to a red heat with carbonaceous matter, it became magnetic, and dissolved in muriatic acid, except $\frac{1}{0.1}$th of a grain, which appeared to be silica, derived from the water evaporated to obtain the precipitate formed by tincture of galls. The muriatic solution afforded a blue precipitate with prussiate of potash, 0.4 were therefore oxide of iron.

According to the experiment (*F*) one quart of the water affords .0421 of a grain of oxide of iron, and by the second .0463, giving a mean of .0442; but the iron in the water is in the state of protoxide; and as the peroxide consists of 66.5 protoxide, and 7.5 oxygen, .0442 will give .0397, the quantity of protoxide of iron in one quart of the water.

16.2 of chloride of silver indicate 6.6 of common salt.

18 of oxalate of lime are produced by 18.6 of sulphate of lime.

18.6 of sulphate of lime afford 32 of sulphate of barytes, which subtracted from 36.7, the whole quantity of sulphate of barytes obtained, leave 4.7 for the sulphate of barytes formed by the sulphate of soda, equivalent to 2.8.

One quart of the water therefore contains.

Carbonic acid gas . .	2.4	inches
Sulphate of lime . .	18.6	grains
Common salt . . .	6.8	
Sulphate of soda . .	2.8	
Carbonate of lime . .	1.6	
Silica	0.4	
Oxide of iron . . .	0.0397	
	30.2397	
Error	.2397	
	30.	

Estimating the sulphate of soda in the crystallized state, one pint of the water contains nearly as follows:

Carbonic acid . . .	$1\frac{1}{5}$ inch
Sulphate of lime . .	$9\frac{1}{3}$ grains
Common salt . . .	$3\frac{4}{10}$
Sulphate of soda .	$3\frac{1}{5}$
Carbonate of lime .	$0\frac{8}{10}$
Silica	$0\frac{2}{10}$
Oxide of iron . . .	$\frac{1}{50}$

§ 194. Dr. Murray has lately published, in the 8th vol. of the Transactions of the Royal Society of Edinburgh, a general formula for the analysis of mineral waters, founded on the idea that the salts obtained from them by evaporation are not necessarily those which existed in the water, but that "the concentration by evaporation must in many cases change the state of combination, and that they may be frequently products of the operation, and not the original ingredients." He considers that the state of combination in which the component parts of salts, their acids and bases, may exist in a mineral water, may be contemplated under two views;—first, that they may be in simultaneous combination, "the whole acids being neutralized by the whole bases;"—secondly, as constituting binary compounds, and that in this case the combinations are those which form the most soluble salts, their separation in less soluble compounds, on evaporation, arising from the influence of the force of cohesion. He proposes, therefore, to obtain separately all the acids and all the bases of the saline ingredients, and then to calculate from these data, the quantities of the respective salts they may be supposed to give rise to, considered as binary compounds of the greatest solubility, and existing independent of each other.

This method could hardly have been adopted a few years since from the very imperfect knowledge then possessed of the composition of the salts; but the great number of accurate analyses of those bodies which have since been made, and the establishment of the Atomic Theory, demonstrating the constant and definite ratio of the combinations of their elements, have removed the difficulties that heretofore existed.

The method proposed by Dr. Murray is as follows: "Reduce the water by evaporation as far as can be done without occasioning any sensible precipitation or crystallization; this, by the concentration, rendering the operation of the re-agents to be employed more certain and complete. It also removes any free carbonic acid.

"Add to the water thus concentrated, a saturated solution of muriate of barytes, as long as any precipitation is produced, taking care to avoid adding an excess. By a previous experiment, let it be ascertained whether this precipitate effervesces or not with diluted muriatic acid, and whether it is entirely dissolved. If it is, the precipitate is of course carbonate of barytes, the weight of which when it is dried gives the quantity of carbonic acid; 100 grains containing 22 of acid. If it do not effervesce it is sulphate of barytes, the weight of which, in like manner, gives the quantity of sulphuric acid; 100 grains dried at a low red heat containing 34 of acid. If it effervesce and is partially dissolved, it consists both of carbonate and sulphate. To ascertain the proportions of these let the precipitate be dried at a heat a little inferior to redness, and weighed; then submit it to the action of diluted muriatic acid; after this wash it with water, and dry it by a similar heat; its weight will give the quantity of sulphate, and the loss of weight that of he carbonate of barytes.

"By this operation the carbonic and sulphuric acids are entirely removed, and the whole salts in the water are converted into muriates. It remains, therefore, first to discover and estimate the quantities of the bases present, and then to complete the analysis, to find the quantity of muriatic acid originally contained. Add to the clear liquor a saturated solution of oxalate of ammonia as long as any turbid appearance is produced. The lime will be thrown down in the state of oxalate. This precipitate being washed, may be dried; but as it cannot be exposed to a red heat without decomposition, it can scarcely be brought to any uniform state of dryness with sufficient accuracy to admit of the quantity of lime being estimated from its weight. It is therefore to be calcined with a low red heat, by which it is converted into carbonate of lime, 100 grains of which are equivalent to 56 of lime. But as a portion of carbonic acid may be expelled, if the heat is raised too high, or a little water retained if it is not high enough, it is proper to convert it into sulphate by adding sulphuric acid in slight excess, and then exposing to a full red heat. The dry sulphate of lime will remain, 100 grains of which contain 41.5 of lime. (a)

"(a) The only source of error to which this step of the analysis is liable, is that which will arise if more barytes has been used in the first operation than was necessary to precipitate the sulphuric and carbonic acids. It will be thrown down in the state of oxalate of barytes, and be converted into carbonate and sulphate, and thus give the apparent proportion of lime too large. This is obviated of course by taking care to avoid using an excess of barytes. To render the operation of the oxalate of ammonia as perfect as possible in precipitating the lime, the water should be considerably reduced by evaporation, taking care to avoid any separation of any of its ingredients."

"The next step is to precipitate the magnesia; add to the clear liquor poured off after the precipitation of the oxalate of lime, heated to 100°, and if necessary, reduced by evaporation, a solution of carbonate of ammonia; and immediately drop in a strong solution of phosphoric acid, or phosphate of ammonia, continuing this addition with fresh portions, if necessary, of carbonate of ammonia, so as to preserve an excess of ammonia in the liquor as long as any precipitation is produced. Let the precipitate be washed; when dried by a heat not exceeding 100°, it is the phosphate of ammonia and magnesia containing 0.19 of this earth; but it is better for the sake of accuracy, to convert it into phosphate of magnesia by calcination for an hour at a red heat: 100 grains then contain 40 of magnesia.

"Evaporate the liquor remaining after the preceding operations to dryness, and expose the dry mass to heat as long as any vapours exhale, raising it towards the end to redness. The residual matter is muriate of soda, 100 grains of which are equivalent to 53.3 of soda, and 46.7 of muriatic acid. It is not however to be considered necessarily as the quantity of muriate of soda contained in the water; for a portion of soda may have been present above that combined with muriatic acid, united, for example, with portions of sulphuric or carbonic (*a*) acid; and from the nature of the analysis, this, in the progress of it, or rather in the first step, that of the removal of these acids by the muriate of barytes, would be combined with muriatic

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(*a*) If with *carbonic* acid its alkaline properties must be evident in the recent water, at least when reduced by evaporation, by the test of turmeric paper.

acid. It does not therefore give the original quantity of that acid; but it gives the quantity of *soda*, since no portion of this base has been abstracted, and none introduced."

"The quantity of muriatic acid may have been either greater or less than that in the muriate of soda obtained. If the quantity of soda existing in the water exceeded what the proportion of muriatic acid could neutralise, this excess of soda being combined with sulphuric or carbonic acid; then, in the removal of these acids by muriate of barytes, muriatic acid would be substituted, which would remain in the state of muriate of soda; and if the quantity considered as an original ingredient were estimated from the quantity of this salt obtained, it would be stated too high. Or if, on the other hand, more muriatic acid existed in the water than what the soda present could neutralise, the excess being combined with the other bases, lime or magnesia, then, as in the process by which these earths are precipitated, this portion of the acid would be combined with ammonia, and afterwards dissipated in the state of muriate of ammonia; if the original quantity were inferred from the weight of the muriate of soda obtained, it would be stated too low.

"To find the real quantity therefore, another step is necessary; estimate directly the quantity of muriatic acid in a given portion of the water, by abstracting any sulphuric or carbonic acid by nitrate of barytes, and then precipitating the muriatic acid by nitrate of silver or nitrate of lead. The real quantity will thus be determined with perfect precision, and the result will form a check on the other steps of the analysis, as it will lead to the detection of any error in the estimate of the other ingredients; for when the quantity is thus found, the quantities of these must bear that proportion to it which will correspond with the state of neutralization."

"Thus, by these methods, the different acids and the different bases are discovered, and their quantities determined. And the results of the analysis may be stated in three modes: 1st, the quantities of the acids and bases. 2dly. The quantities of the binary compounds as inferred from the principle, that the most soluble compounds are the ingredients; which will have at the same time the advantage of exhibiting the most active composition which can be assigned, and hence of best accounting for any medicinal powers the waters may possess. And 3dly, the quantities of the binary compounds, such as they are obtained by evaporation, or any other direct analytic operation."

"With regard to other ingredients either not saline, or more rarely present, it will in general be preferable, when their presence has been indicated by the employment of tests, or by results occurring in the analysis itself, not to combine the investigation to discover them with the general process above described, but to operate on separate portions of the water, and to make the necessary allowance for their quantities in estimating the other ingredients. The quantity of iron, for example, in a given portion of the water, may be found by the most appropriate method. Silica will be discovered by the gelatinous consistence it gives on evaporation, and forming a residue insoluble in acids, but dissolved by a solution of potash. Alumina may be discovered in the preliminary application of tests, by the water giving a precipitate with carbonate of ammonia, which is not soluble, or is only partially soluble in weak distilled vinegar, but is dissolved by boiling in a solution of potash, or by its precipitation from the water sufficiently evaporated by succinate of soda; or in conducting the process itself, it will remain in solution after the precipitation of the lime by the oxalic acid, and be detected by the turbid appearance produced on the addition of the carbonate of ammonia previous to the addition of the phosphoric acid to discover the magnesia. Its quantity may then be estimated from its precipitation by carbonate of ammonia, or by other methods usually employed. Silica will also be precipitated in the same stage of the process; its separation from the alumina may be effected by submitting the precipitates thoroughly dried, to the action of diluted sulphuric acid. Potash, when present, which is very seldom to be looked for, will remain at the end, in the state of muriate of potash. Muriate of platina will detect its presence, and the muriate of potash may be separated by crystallization from the muriate of soda."

"There is another mode in which part of the analysis may be conducted, which although perhaps a little less accurate than that which forms the preceding formula, is simple and easy of execution, and which may hence occasionally be admitted as a variation of the process; the outline of which therefore, I may briefly state."

"The water being partially evaporated, and the sulphuric and carbonic acids, if they are present, being removed by the addition of muriate of barytes, and the conversion of the whole salts into muriates effected in the manner already described; the liquor may be evaporated to dryness, avoiding an excess of heat, by which the muriate of magnesia, if present, might be decomposed; then add to the dry mass six times its weight of rectified alcohol (of the specific gravity at least of ·835) and agitate them occasionally during twenty-four hours, without applying heat. The muriates of lime and magnesia will thus be dissolved, while any muriate of soda will remain undissolved. To remove the former more completely, when the solution is poured off, add to the residue about twice its weight of the same alcohol, and allow them to stand for some hours, agitating frequently. And when this liquor is poured off, wash the undissolved matter with a small portion of alcohol, which add to the former liquors."

"Although muriate of soda by itself is insoluble, or nearly so, in alcohol of this strength, yet when submitted to its action along with muriate of lime or of magnesia, a little of it is dissolved. To guard against error from this therefore, evaporate or distil the alcoholic solution to dryness, and submit the dry mass, again, to the action of alcohol in smaller quantity than before; any muriate of soda which had been dissolved will now remain undissolved, and may be added to the other portion; or at least any quantity of it dissolved must be extremely minute. A slight trace of muriate of lime or of magnesia may adhere to the muriate of soda, but when a sufficient quantity of alcohol has been employed, the quantity is scarcely appreciable; and the trivial errors from these two circumstances counteract each other, and so far serve to give the result more nearly accurate."

"Evaporate the alcohol of the solution, or draw it off by distillation. To the solid matter add sulphuric acid, so as to expel the whole muriatic acid; and expose the residue to a heat approaching to redness, to remove any excess of sulphuric acid. By lixiviation with a small portion of water, the sulphate of magnesia will be dissolved, the sulphate of lime remaining undissolved, and the quantities of each, after exposure to a low red heat, will give the proportions of lime and magnesia. The quantity of soda will be found from the weight of the muriate of soda heated to redness; and the quantities of the acids will be determined in the same manner as in the general formula."

"This method is equally proper to discover other ingredients which are more rarely present in mineral waters. Thus alumina will remain in the state of sulphate of alumina along with the sulphate of magnesia, and may be detected by precipitation by bicarbonate of ammonia. Silica will remain with the muriate of soda after the action of the alcohol, and will be obtained on dissolving that salt in water. And iron will be discovered by the colour it will give to the concentrated liquors, or the dry residues, in one or other of the steps of the operation."

Dr. Murray obtains the quantity of gases a water may contain, by processes similar to those detailed in the preceding pages. M. Thenard remarks of Dr. Murray's method, that it is certainly good, but not in his opinion preferable to the one previously stated; which presents all the advantages of Dr. Murray's, since it equally enables us to obtain separately the quantities of the different acids and bases; and it is even more generally applicable to all cases.

Sea-water.—Sea-water which may be considered as a true mineral water, has been analysed by many chemists whose experiments prove that the elements of the salts it contains, are soda, lime and magnesia, and sulphuric and hydrochloric acids. These five substances by their combinations are capable of forming six salts, but it is not probable that they exist all together in solution.

Be that as it may, the following are the results of the most recent analyses.

M. M. Bouillon Lagrange, and Vogel, obtained from 100 parts of the sea water taken near Bayonne, in the Gulf of Gascony,

Sea salt	2.510
Hydrochlorate of magnesia . .	0.350
Sulphate of magnesia	0.578
Carbonates of lime and magnesia	0.020
Sulphate of lime	0.015
Carbonic acid	0.023
	3.496

Dr. Murray's analysis of the water of the Frith of Forth gave, in an hundred parts,

Lime . . .	0.040	Sea salt . . .	2.470
Magnesia . .	0.202	Hydrochlo. mag.	0·315
Soda . . .	1.318 or	Sulph. of magnesia	0.212
Sulphuric acid	0.197	Sulph. of lime	0.097
Hydrochlo. do.	1.337		3.094
	3.094		

Considering that the binary compounds formed in a dilute solution, must be those which are most soluble, he supposes the 100 parts of sea water analysed contain,

Sea salt	2.180
Hydrochlorate of magnesia . .	0.486
Hydrochlorate of lime . . .	0.078
Sulphate of soda	0.350
	3.094

Dr. Murray also found carbonic acid in sea water, but he does not admit either carbonate of lime or carbonate of magnesia, because the precipitate by nitrate of barya gave no effervescence with acids. He conceives the carbonates to arise from the decomposition of the hydrochlorates of lime and magnesia, in the process of evaporation to dryness.

CHAPTER VII.

Of the Analysis of Vegetable and Animal Substances.

DIVISION THE FIRST.

§ 195. The compounds which constitute the vegetable and animal kingdoms differ from every other species of matter in their peculiar organized structure, and especially, in a chemical view, in this, that all of them without a single exception are decomposed by high temperatures. They are also liable to spontaneous decomposition after death, and their elements entering into new combinations become serviceable to fresh processes for the support of animal life and of vegetation, and what to-day delights us in the fragrance of the rose may at a future season nourish us as bread, or exhilirate as wine.

The elements of inorganic matter are generally combined in very simple proportions, one and one, or one and two, &c.; in organized bodies, on the contrary, their proportions are much more complicated; several atoms of one species of matter are united with several others of different species, and hence their mutual attractions are more unstable than the attractions between the elements of the former substances; and hence, too, one reason of our utter inability to reproduce even the simplest body of this class, when once its elements have been separated; though to this another cause must be added of still greater force;—the powers of life are not in the hands of man,—that principle, which once lost, organization soon ceases, is only subservient to his will, from whose bounty we have ourselves received it. The variety of organized bodies in which nature, has as it were, playfully, but beautifully indulged, from the majestic grandeur of the oak, to the scarcely visible moss,—from the mountainous elephant to the microscopic insect, seems almost infinite;—yet, to produce all this multiplicity of form, and all the secretions and products it gives rise to, a very few elements suffice for the creative power that called them into being. Vegetable substances seldom contain, as essential, more than three principles, oxygen, hydrogen, and carbon, and sometimes azote;—animal matters generally contain all these, but no more. (a)

With four simple elements then, (a brief alphabet for so comprehensive a history,) has a bountiful Omnipotence composed the beautiful volume of the living world, where, turn what page we may, fresh loveliness meets the eye, fresh cause of admiration and delight.

The subject resolves itself into two parts; the first regards the nature of the proximate principles of vegetable and animal bodies; the second, the investigation of the ultimate principles. By the proximate principles, we mean those compound substances found in vegetable and animal bodies which are distinguished by peculiar characters, by the ultimate prin-

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(a) Lime and phosphorus are indeed essential ingredients in the formation of bone, and some other substances are also found in organized bodies; but the latter are in such extremely minute proportion, that we can scarcely consider them as essential, though in strict propriety we are not justified perhaps in calling one element essential rather than another, whatever difference there may be in their proportions.—Berzelius proposes to call those substances which are always found in organized bodies, but in these very minute quantities, *secondary* elements, and the others *primary*.—(Annals of Philosophy, vol. iv. p. 328.)

ciples, those elements of which the proximate principles are composed.

All vegetable substances are either solid or liquid,—many are volatile, as alcohol, ether and the essential oils. Dr. Thomson arranges the substances found in vegetables under five heads;

1.—Substances soluble in cold water.
2.—Substances insoluble in cold water, but partly soluble in hot water.
3.—Fusible and inflammable substances, insoluble in water, but (generally) soluble in alcohol or ether.
4.—Substances insoluble in water, alcohol and ether, and which have a fibrous or woody texture.
5.—Extraneous substances, belonging to the mineral kingdom, but found in small quantities in vegetables.

Of the distinguishing Properties of the proximate Principles of Vegetables.

OF ACIDS.

§ 196. Almost all the vegetable acids in their most uncombined state are solid, colourless, heavier than water, and inodorous. They redden vegetable blues with different degrees of force, and, except the fungic, malic, suberic, zumic and lampic, are crystallizable. They all dissolve in water, and most of them in alcohol. (a)

(a) Dr. Thomson determines the solubility of salts in water and alcohol as follows. He puts a certain quantity of the fluid into a tube, The greater part of the vegetable acids exist ready formed in nature; three of them are both natural and artificial products, viz. the acetic, malic, and oxalic; six are only formed by art,—camphoric, mucous, pyrotartaric, zumic, lampic, and pyromucic.

§ 197. *Acetic acid* exists ready formed in the sap of many vegetables, but is generally obtained by fermentation; when very pure it crystallizes at about 55°; it is colourless, has a very pungent odour, and strong acid taste, and reddens vegetable blues deeply. Its specific gravity at 62° is 1.063. It boils at a temperature above 212°, and rises in vapour without decomposition. (*a*)

§ 198. *Malic acid* exists in the apple; it is brown, probably from the presence of some foreign substance; not very acid to the taste, but reddens litmus strongly. It does not crystallize; when spread in thin layers and dried, it has the appearance of varnish; it is soluble in alcohol; is very liable to decompose by keeping, and become mouldy; by nitric acid it is converted into oxalic acid. It gives a white precipitate with barya water, and with the nitrates of lead, silver, and mercury, all of which are soluble in an excess of malic acid, and in nitric acid.

§ 199. *Oxalic acid* exists in the oxalis acetosella; it has a very acid taste, and acts strongly on vegetable

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and suspends a crystal in the tube. If it be soluble, a current of liquid may be perceived running down from the crystal to the bottom of the tube. If it be insoluble no such current is visible. This method is equally applicable to the solid acids, and other substances. (Annals of Philosophy, vol. xii. p. 103.)

(*a*) At the end of the account of the properties of the vegetable acids will be found a table containing those of the salts they respectively form with the bases of potassa, barya, and lead.

blues. It crystallizes in long transparent colourless quadrilateral crystals with dihedral summits; it requires twice its weight of water at common temperatures for its solution; it undergoes no change by exposure to the air, and is not readily soluble in alcohol; when placed in contact with that liquid its crystals crack with a slight noise. It has a strong attraction for lime, which it precipitates from its neutral combination, with sulphuric acid. It precipitates the sulphate and hydrochlorate of copper blueish white; nitrate of silver white; and nitrate of protoxide of mercury in white gelatinous flakes.

§ 200. *Benzoic acid*, formed from gum benzoin, is solid, white, and slightly ductile, reddens tincture of litmus; has rather a bitter taste, but, when pure, no smell; it crystallizes in long white opaque prisms, with a satiny lustre. By heat in close vessels benzoic acid fuses readily; a portion is decomposed, the rest sublimes and crystallizes in the neck of the retort; in open vessels it exhales a white combustible vapour extremely irritating to the lungs. It is permanent in the air. Boiling water dissolves $\frac{1}{25}$th of its weight of benzoic acid; at common temperatures it takes up only $\frac{1}{200}$dth: it is soluble in twice its weight of alcohol, from which it is thrown down by water. The strongest mineral acids have little action on it.

§ 201. *Citric acid* exists in lemons; it crystallizes in rhomboidal prisms; its taste is extremely sharp and acid; it reddens litmus strongly, undergoes no change by exposure to the air, but when heated in it, it fuses, swells up, and is dissipated in acrid vapours, without leaving any residuum; it dissolves in $\frac{3}{4}$ths of its weight of water at common temperatures; it is also soluble, but in a less degree, in alcohol. The aqueous solution is very liable to decompose and become mouldy. It is converted by nitric acid into oxalic acid.

§ 202. *Boletic acid* was obtained by M. Braconnot from the boletus pseudo igniarius; it is very white, not altered by exposure to the air, and formed of small granular prisms, which have an acidulous flavour, similar to that of tartar. At the temperature of 60° it requires 180 parts of water for its solution, but is soluble in 45 parts of alcohol. The aqueous solution reddens tincture of litmus, and precipitates peroxide of iron completely, of a red colour, the supernatant liquor remaining colourless; the protoxide is not affected by it.—(Annales de Chimie, vol. lxxx.) This is the acid described by Thomson and Henry.

Since his former experiments, M. Braconnot has discovered another acid in fungi, which being more generally contained in them, he has named *fungic* acid. Its flavour is very sharp; it is colourless, deliquescent, and not crystallizable.

The properties of the salts formed by both the acids with bases of potassa, barya, and lead, have considerable resemblance.—(Annales de Chimie, vol. lxxxvii.) This is the fungic acid described by M. Thenard, (vol. iii. p. 110.)

§ 203. *Gallic acid* is obtained from nutgalls; it has an acid astringent flavour, reddens tincture of litmus strongly, and crystallizes in white brilliant plates. It is not deliquescent in the air; it is soluble in three parts of boiling and in 20 of cold water. It is very soluble in alcohol; its aqueous solution becomes mouldy by keeping; it sublimes by heat.

§ 204. *Ellagic acid.*—M. Braconnot has lately discovered in the gall nut a new substance, which he considers to be an acid. He obtained it in the following manner:

The deposit formed in an infusion of galls, which had fermented, being treated with boiling water, left a powder of a light fawn colour, and soft to the touch like starch. This insoluble powder combined with a weak solution of potassa, with a sensible disengagement of heat, and formed a slightly alkaline liquor, of a very deep yellow colour, which being filtered and set aside, let fall a pearly deposit in considerable quantity. This deposit was washed 'till the water passed colourless, and a neutral salt, of a greenish white colour when dry, was obtained, which being decomposed by weak hydrochloric acid, the new substance was left in a separate state. It possesses the following properties:

It is an insipid white powder, slightly inclining to brownish red, insoluble in boiling water, and scarcely reddens the colour of litmus paper. It does not decompose the alkaline subcarbonates, but combines readily with the pure alkalies, and neutralizes them. These compounds are insoluble in water, but soluble in a very weak alkaline solution, to which they impart a deep yellow colour. Ellagate of potassa forms brilliant pearly scales like talc. When ellagic acid is mixed with nitric acid, and very gently heated, the mixture acquires a reddish tint, which gradually becomes more intense and passes to a deep blood red. By continuing the action of the nitric acid, a large quantity of oxalic acid is formed. The new substance does not fuse by heat, but burns without flame and scintillates slightly. By distillation, it is partly decomposed, charcoal is deposited, and a yellow vapour evolved, which condenses in transparent greenish yellow acicular crystals, similar to some of the varieties of uranite; they are insipid, and insoluble in boiling water, alcohol and ether. Ellagic acid dissolves in concentrated sulphuric acid, from which it is thrown down again by water. (Annales de Chimie, vol. ix. p. 187, new series.)

M. Braconnot seems unfortunate in his nomenclature; he called the acid obtained from rice *Nanceic*, from Nancy, the place of his residence, which Dr. Thomson much more properly named *zumic*. He has called the above new substance *ellagique*, from the word *galle* reversed. It is to be hoped Dr. Thomson will invent a better term for it in his next edition; if the substance shall be then found to hold the rank assigned it by M. Braconnot.

§ 205. *Kinic acid* is obtained from the quinquina, or yellow Peruvian bark; it is extremely acid to the taste, crystallizes, is permanent in the air, and fuses by heat; it is generally tinged of a brown colour, and its acid flavour slightly mixed with bitter, both probably from some impurities. It does not give a precipitate with the nitrates of silver, mercury, or lead.

§ 206. *Laccic acid* is obtained from stick-lac; it is crystallizable, its colour is wine yellow; it has an acid flavour, and is soluble in water, alcohol and ether. It precipitates lead and mercury white; but does not render lime water, or the nitrates of silver or barya, turbid. Whether pure, or combined with a base, it gives a white precipitate with salts of iron.

§ 207. *Meconic acid* is obtained from opium; it is white, and crystallizes sometimes in needles, sometimes in square plates, or very elongated octohedra. It fuses at about 250°. and sublimes unaltered. It reddens litmus, and is very soluble in water and alcohol; it gives no precipitate with salts of peroxide of iron, but changes the solution to a deep red colour; it first turns the blue colour of solution of sulphate of copper to a beautiful emerald tint, and after a certain time, a pale yellow precipitate is deposited. It also gives a precipitate with corrosive sublimate.

§ 208. *Mellitic acid* is obtained from the mineral called honey-stone or mellite; it has at first a mild acid flavour, which afterwards becomes bitter; it crystallizes in small hard prisms, or fine needles of a brownish colour, which sometimes adhere together so as to form little globules. It is sparingly soluble in water. Nitric acid changes its colour to straw yellow, but is incapable of converting it into oxalic acid. It gives a white precipitate with nitrate of mercury, a green one with acetate of copper, and with nitrate of iron, a cream yellow.

§ 209. *Moroxylic acid* is obtained from a saline efflorescence on the bark of the mulberry tree (Morus alba). When quite pure it crystallizes in colourless transparent prisms; it has a sharp taste, and reddens litmus; it is permanent in the air, and very soluble both in water and alcohol; it is sublimed by heat.

§ 210. *Sorbic acid* exists in the sorbus aucuparia, it is a transparent, colourless, inodorous fluid; when evaporated, it forms a deliquescent uncrystallizable mass, very soluble in water and in alcohol; its taste is excessively acid. According to Vauquelin, when evaporated to the consistence of a syrup, it crystallizes in little mammulæ: fuses by heat, and when the whole of its water is driven off, sublimes and crystallizes in very acid white needles, depositing at the same time a little charcoal; hence it does not sublime unaltered. It is very readily converted into oxalic acid, by the action of nitric acid.

§ 211. *Succinic acid* is obtained from amber; it crystallizes in white transparent prisms, which have an acid flavour, and redden litmus; are soluble in 96 parts of water at the temperature of 50°, and in two parts at 212°; boiling alcohol dissolves more than half its weight of this acid, but a great portion separates again on cooling. It fuses by heat and sublimes, but not unchanged. It is not altered by exposure to the air. Sulphuric and nitric acids dissolve succinic acid, without decomposing it; when heated with hydrochloric acid, it forms a jelly.

§ 212. *Tartaric acid* is obtained from wine-lees. When a solution of tartaric acid is very much concentrated, and left some days at rest, it forms laminated crystals of indeterminate forms; if these be triturated, they are reduced to a pasty mass; by heat they fuse, and swell up. This acid is very soluble in water, and its solution is not liable to spontaneous decomposition, unless very much diluted. It is sparingly soluble in alcohol. It combines with potassa in two proportions; the neutral salt is readily soluble in water, but the supertartrate very imperfectly so. Hence its presence is easily detected, by dropping in by degrees a solution of potassa, to a liquid supposed to contain it; if tartaric acid be present, the supertartrate will precipitate in the form of a white gritty powder.

Nitric acid readily converts the tartaric into oxalic acid.

§ 213. *Camphoric acid* is obtained from camphor; it forms snow white plumose crystals, which effloresce in the air, have a slightly bitter taste, something like saffron, and redden vegetable blues. It is soluble in 100 parts of cold water, and in 96 at the temperature of 60°; boiling water dissolves one-tenth of its weight of this acid, and alcohol rather more than an equal weight of it. The solution has the consistence of thin syrup. It is soluble in boiling alcohol in all proportions. It melts by a gentle heat and sublimes; on hot coals it is dissipated in dense aromatic fumes; it is soluble in the mineral acids, and in the essential and fixed oils.

§ 214. *Saclactic acid* is obtained from gums; it is a white gritty powder, with a weak acid taste, and reddens litmus slightly. When decomposed by heat in close vessels, besides the usual products afforded by vegetable matters, a whitish substance sublimes and condenses in plates in the neck of the retort, which, according to Tromsdorff, is succinic acid. Saclactic acid undergoes no alteration in the air; boiling water dissolves $\frac{1}{60}$th of its weight, a portion of which crystallizes on cooling. It is quite insoluble in alcohol.

§ 215. *Pyrotartaric acid* is obtained by the distillation of tartar; it is solid, extremely acid to the taste, and reddens vegetable blues strongly; it is very soluble in water, and by spontaneous evaporation separates again in crystals, whose form has not been well ascertained. Heated in a retort it fuses, is partly decomposed, and partly sublimed in white scales, which condense in the neck; in open vessels it flies off in white fumes, without leaving any residuum.

§ 216. *Suberic acid* is obtained from cork; it is white and pulverulent, with a slight acid flavour, and reddens litmus very faintly. Water at 140° dissolves $\frac{1}{38}$th of its weight of this acid, at 60° only $\frac{1}{80}$th. It is much more soluble in alcohol, from which water precipitates a part of it. When heated in a retort it melts, and on cooling crystallizes in needles; by increasing the heat, vapours are given off, which condense in the neck in long needle-shaped crystals. On burning coals it is volatilized entirely, and exhales the smell of tallow. Nitric acid has no action on it; it precipitates the nitrate and acetate of lead, nitrate of silver, hydrochlorate of tin, and sulphate of iron; but not the sulphates of copper or zinc.

§ 217. *Zumic acid* is obtained from rice; it is a colourless very acid fluid, which when evaporated to the consistence of a syrup, does not crystallize. It forms, with the white oxide of manganese, a soluble salt which crystallizes in tetrahedra; with oxide of zinc, one which assumes the form of square prisms. Zumate of protoxide of iron crystallizes in fine tetrahedral needles, of little solubility, and permanent in the air. Zumate of peroxide of iron does not crystallize.

Zumic acid dissolves oxide of silver, and forms a salt which crystallizes in needles that have a silky lustre, and radiate from a common centre. They are soluble in 20 parts of water at 66° (*a*).

§ 218. *Lampic acid.*—If a coil of fine platina wire $\frac{1}{100}$th of an inch in diameter, be so placed round the wick of a spirit lamp, as to leave two or three turns

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(*a*) According to Vogel, this acid is identical with the lactic acid of Scheele and Berzelius (Annals of Philosophy, vol. xii. p. 391.)

above the wick, and the flame extinguished as soon as the wire is red hot, the part above the wick will continue to glow, till the whole of the liquid in the lamp is consumed.

If alcohol or ether be the liquid employed, a peculiar acid is formed by this process of slow combustion, whose properties have lately been examined by Mr. Daniell.

Mr. Daniell has proposed the term *Lampic acid*, to denote this new substance, as a name which "will record at once its mode of formation, and its connection with that brilliant chain of investigation, which is the boast of science and triumph of humanity."

Lampic acid formed from ether is a colourless fluid, with an intensely sour taste, and pungent odour: its vapour is very disagreeable, irritating and oppressive to the lungs. Its specific gravity varies, when first prepared from 1000 to 1008, by careful evaporation it may be obtained as high as 1015. It reddens vegetable blues, and decomposes all the earthy and alkaline carbonates. The lampates of potassa and soda are deliquescent, that of ammonia is volatile below 212°, exhaling a disagreeable smell, like that of burning animal matter.

Lampate of barya crystallizes in needles.

Lampate of lime is deliquescent, caustic and bitter to the taste, but perfectly neutral.

Lampate of magnesia is sweetish and astringent. All these salts burn with flame and leave a carbonaceous residuum, which continues to glow after the flame is extinguished. Lampic acid precipitates metallic gold from its solution in hydrochloric acid;

the lampates of potassa and ammonia produce the same effect, and the interior of the tube becomes covered with a thin coat of gilding, which transmits a beautiful purple light.

Platina is not reduced by lampic acid, but the colour of a solution of its hydrochlorate is heightened by it. Both the lampates of potassa and ammonia throw down from it a yellow and very crystallizable salt, neither of which is separately reduced at a boiling heat; but if the two be mixed together, an instantaneous precipitation ensues, which lines the tube with a coating of metallic platina, and the solution remains colourless.

Lampic acid precipitates metallic silver from the nitrate; it dissolves oxide of silver, and gives a sea-green solution.

Lampic acid, added to a solution of nitrate of mercury and warmed, exhibits a very beautiful phenomenon. A metallic shower takes place, and brilliant globules of quicksilver soon accumulate at the bottom of the vessel.

Lampic acid dissolves red oxide of mercury, and forms a bulky white salt, sparingly soluble in water.

From an experiment with a mixture of the acid and black oxide of manganese, the decomposition of the metallic oxides by lampic acid, appears to be owing to the abstraction of their oxygen by the carbon of the acid.

Lampic acid dissolves black oxide of copper, the solution is blue, and affords rhomboidal crystals by gentle evaporation; by boiling, the copper is thrown down of a deep red colour.

Strong sulphuric acid instantly blackens lampic acid, and disengages a quantity of carbon. With nitric acid, nitrous gas is evolved, and oxalic acid formed.

(Journal of Science and the Arts, vol. vi. p. 318.)

§ 219. Pyromucic acid has been lately discovered by M. Houtou Labillardiere (Annales de Chimie, vol. ix. p. 365.) He obtained it by distilling saclactic acid in a strong heat. It is an inodorous, white crystalline solid, is strongly acid, and fuses at a temperature of about 266°; at a higher heat it sublimes, and condenses into a liquid which crystallizes as it cools, and its surface is covered with very delicate crystals; on hot coals it fuses, and sublimes in white pungent vapours; it reddens litmus strongly; it is not deliquescent, but much more soluble in boiling water than in cold; a saturated hot solution of pyromucic acid, deposits crystals as it cools, in small elongated plates, crossing each other in every direction. Its analysis by oxide of copper gave

Oxygen . .	45.8
Carbon . .	52.1
Hydrogen . .	2.1
	100.0

Pyromucate of barya is composed of	acid	57.7
	barya	42.2
		99.9

Consequently 100 of the acid, saturate 73.13 of the base, which contain 7.6 of oxygen; and $\frac{45.8}{7.6} = 6$ the number of atoms of oxygen, or $(7.5 \times 6) \ldots 45.0$

45.8 : 52.1 : : 45 : 51.3 . . . carbon

45.8 : 2.1 : : 45 : 2 . . . hydrogen

The atomic composition of pyromucic acid, therefore is,

$$\begin{aligned} 7.5 \times 6 &= 45.0 \text{ oxygen} \\ 5.7 \times 9 &= 51.3 \text{ carbon} \\ 1 \times 2 &= 2.0 \text{ hydrogen} \\ &\overline{98.3} \end{aligned}$$

The equivalent number of its atom as obtained from pyromucate of barya, is 99.1.

Pyromucic acid dissolves carbonate of lead, and forms a very singular compound with the oxide; when the solution is evaporated, brownish, transparent, liquid globules, of an oily appearance, form on its surface, which being separated, assume on cooling the softness and tenacity of pitch, and at last become solid, opaque and whitish; by continuing the evaporation, the whole liquid is converted into this kind of salt, from which the acid and oxide of lead may be obtained.

§ 220. In the annexed tables, I have endeavoured to bring under one general view, the most striking characters of the remaining vegetable substances. A few short remarks on each, are added in the following sections, containing such particulars, as could not well be included in the tables. I have in general followed the arrangement adopted by Dr. Thomson.

§ 221. *Sugar.*—Several plants afford this substance; that which is obtained from the sugar cane (arundo saccharifera) is the subject of the present article. When dissolved in water, and mixed with yeast, or any other ferment, and kept at a temperature between 60° and 80°, sugar is decomposed and converted into carbonic acid and alcohol. The sweet taste and appearance of sugar require no description. It usually crystallizes in four or six sided prisms. When distilled it affords water, acetic acid, oil, charcoal, carbonic acid, and hydruretted carbon.

§ 222. *Sarcocoll;* colour yellow, resembles gum arabic in appearance, smell like that of aniseed, taste sweetish bitter, does not crystallize. It is distinguished from gum and mucilage, by the action of tannin.

§ 223. *Gum*, when pure, is colourless, insipid and inodorous. Hydrochlorate of peroxide of iron dropped into strong mucilage, converts the whole into a brown semi-transparent jelly, not easily re-dissolved by water. Silicated potassa is the best test for gum; it throws down a white flaky precipitate, from very dilute mucilage.

§ 224. *Mucus* exists in the roots, leaves, and seeds of a great variety of plants. In taste and appearance it resembles the mucilage of gum arabic. The mucus, referred to in the table, is that obtained from linseed.

§ 225. *Jelly* exists in some fruits, as currants, gooseberries, &c.; when the acid is drained off from the gelatinized juice, the jelly concretes into a hard transparent brittle mass, possessing most of the properties of gum. When pure it is colourless. By long boiling it loses the property of gelatinizing on cooling.

§ 226. *Ulmin* derives its name from a spontaneous exudation from the elm; it forms a constituent in the bark of most trees. Its colour is dark brown. It is insipid and inodorous.

The colouring matters of vegetables are extremely numerous; only three have been particularly examined.

§ 227. *Polychroite* is the colouring matter of saffron. It is intensely yellow, but loses its colour when the aqueous solution is exposed to the sun. When it is distilled, an acid water, and a lemon yellow oil, first come over; then a darker oil, carbonic acid and hydruretted carbon are also disengaged.

§ 228. *Hematin* is the colouring matter of logwood; it affords small brilliant crystals, of a reddish white colour, and slightly astringent, bitter and acrid flavour. Sulphuretted hydrogen passed through its solution in water gives it a yellow colour, which disappears in a few days. Gelatine throws it down in reddish flakes.

§ 229. *Chlorophyle* is the green colouring matter of the leaves of plants. It has lately been examined by M. M. Pelletier and Caventou. (An. de Chimie, vol. lx. p. 194.)

It is a deep green substance, resembling resin in appearance. Iodine and chlorine destroy its colour. When an earthy salt is mixed with the alcoholic solution of chlorophyle, and decomposed by an alkaline sub-carbonate, a green lake is formed, which preserves its colour on being kept exposed to the light.

The bitter taste of many vegetables is owing to the presence of peculiar substances, distinguished by the name of *bitter principles*; a few of them have been particularly examined.

§ 230. *Quassin* is the bitter principle of quassia. It was examined by Thomson. Its taste is intensely bitter. It is solid, slightly transparent, and of a yellowish brown colour.

§ 231. *Scillitin* is the bitter principle of the scilla maritima, or squill; it is white, transparent, and breaks with a resinous fracture; it is easily pulverized: its taste is intensely bitter.

§ 232. *Caffein* is the bitter principle of coffee; it is semitransparent like horn; colour yellow.

§ 233. *Yellow bitter principle* is an artificial substance, formed by the action of nitric acid on various vegetable and animal matters. Its colour is deep yellow; taste intensely bitter; it acts as a permanent dye, and crystallizes in long plates.

§ 234. *Picrotoxine* is the bitter principle of the *cocculus indicus* (menispernum cocculus); it was examined by M. Boullay in 1811. (An. de Ch. vol. lxxx. p. 209). In his first experiments he obtained it by adding acetate of lead, to an aqueous infusion of the berries of the cocculus. The precipitate was separated by the filter, and the liquid evaporated to the consistence of an extract, which was dissolved in alcohol, and the alcoholic solution evaporated to dryness; the alternate action of water and alcohol was repeated till the residuum was completely soluble in both. It was contaminated by a little yellow colouring matter, which water dissolved, and the picrotoxine separated in small crystals.

M. Boullay has lately renewed his enquiries on this substance (see Annals of Philosophy, vol. xii. p. 313), which he now conceives to be a new vegetable alkali analogous to morphia.

He procured it, in his latter experiments, by adding ammonia in excess to a strong infusion of the seeds of the menispermum cocculus, which at first is very acid; a white, granular, crystalline powder precipitated, which, being washed, dissolved partly in alcohol without colouring it, and separated again by spontaneous evaporation, in beautiful silky needles.

The picrotoxine was also obtained from another similar infusion, by neutralizing its acid by boiling it with magnesia; the filtered solution became sensibly alkaline, and a greyish deposit collected, which, by the action of alcohol, afforded crystals similar to those of the former process.

Picrotoxine, thus obtained, had only a weak action on vegetable colours, but readily dissolved in acids, and formed with them neutral salts. The acid of the infusion M. Boullay supposes to be peculiar, and that it exists in the memispermum cocculus, combined with the picrotoxine as a supersalt.

If the second series of experiments be correct (which there seems no reason to question) the substance obtained in 1811 must be an acetate of picrotoxine; and it is not improbable, that many substances which have been obtained in a similar manner, by employing acetate of lead, may in fact be acetates of bases not hitherto known in their pure form. This may perhaps be the case with the daphnin of M. Vauquelin.

§ 235. *Daphnin* is the bitter principle of the daphne alpina. It was obtained from its bark by M. Vauquelin, by means of acetate of lead. (Annales de Chimie, vol. lxxxiv. p. 174.) It has the form of small hard transparent crystals of a greyish colour, and very bitter taste.

§ 236. *Morphia* was obtained from opium by M. Sertüner. It is colourless; its solution is very bitter, and yields short four-sided rectangular pyramidal crystals, occasionally united base to base and forming octohedra. It combines readily with acids, and forms neutral salts. Subcarbonate of morphia is more soluble than morphia. The figure of its crystals is not determined.

The carbonate crystallizes in short prisms.

The acetate in soft prisms, very soluble.

The sulphate in arborescent crystals, very soluble.

The hydrochlorate in plumose crystals, much less soluble; when evaporated, it concretes into a shining white plumose mass on cooling.

The nitrates in prisms grouped together.

The submeconiate in oblique prisms, sparingly soluble.

The tartrate in prisms.

Morphia acts with great energy on the animal system, producing flushings, pain in the head, giddiness, stupor and nausea. The symptoms appear to be alleviated by the use of magnesia. Morphia is separated from its combinations by ammonia.

§ 237. *Vauqueline*, so named in honour of the celebrated French philosopher, was discovered by M. M. Pelletier and Caventou, in the bean of St. Ignatius, and the nux vomica. It is white, and crystallizes in four-sided plates or prisms; its taste is intensely bitter; it resembles morphia in its alkaline properties. (An. de Chimie, vol. viii. p. 383.)

§ 238. *Nicotin* exists in the leaves of tobacco, (nicotiana latifolia.) It is colourless, has an acrid taste, and the peculiar smell of tobacco. It occasions violent sneezing.

§ 239. *Extractive.* Thenard and many other chemists doubt the existence of a peculiar principle to which this name can with propriety be applied. The term *extract* originally meant all those substances which were extracted from plants by means of water, and remained in a dry mass after the water was evaporated. It is obvious that such a product must be very compound, and vary with the nature of the plants from which it is obtained. Rouelle divided extracts into three classes: mucilaginous, resinous and saponaceous. The first are soluble in water, the second in alcohol, and the third in both. Fourcroy and Vauquelin consider that one peculiar principle is the basis of all the three, to which their most characteristic properties are owing, though each is rendered impure by the mixture of other substances; and this they call the extractive principle. Schrader supposed it to be identical with Rouelle's saponaceous extract. This subject is still involved in considerable obscurity, but it would be improper not to state the characters by which this principle is supposed to be distinguished, though even in that respect chemists are not decided. Vegetable chemistry is yet in its infancy; as it advances, it is most likely that many substances now regarded as peculiar proximate principles will be struck out of the list, and others admitted, whose existence is at present unknown to us. I shall state the properties as detailed by Dr. Thomson.

It is solid, and transparent when obtained by slow evaporation, with a strong taste, differing according to the plant from which it is obtained; insoluble in *absolute* alcohol, (*a*) but soluble in alcohol when it contains water. By repeated solutions and evaporations, extractive acquires a deeper colour, and becomes insoluble in water; wool, cotton, or thread impregnated with alum are dyed of a fawn colour by extractive; when distilled, it yelds an acid liquid impregnated with ammonia.

§ 240. *Emetin* is obtained from ipecacuanha; it is in the form of brownish red transparent scales; inodorous, bitter, and slightly acid.

§ 241. *Asparagin* is obtained from the juice of asparagus. It crystallizes in white transparent rhomboidal prisms; it is hard and brittle; its taste is cool and slightly nauseous.

§ 242. *Cerasin* is obtained from gum tragacanth; or rather, according to Thomson, that substance is pure cerasin. It is solid, with the appearance and taste of gum, swells up, and becomes transparent and gelatinous in water, but does not dissolve; when the jelly is triturated with pure water, a homogeneous mucilage is formed, containing one per cent. of cerasin. It is this solution to which the action of the metallic salts in the tables refer.

§ 243. *Inulin* is obtained from the roots of the inula helenium, (elecampane); it is in the form of a white powder, like starch. When distilled it yields a brown acid liquid, but no oil. It melts on hot coals, and emits a thick smoke with an odour resembling that of burnt sugar.

(*a*) It would have been much more satisfactory to have stated in the annexed tables the specific gravity of the alcohol employed; but it is so seldom mentioned by the authors that I have been obliged to omit it. Much confusion might be avoided if it were a matter of course to define its strength whenever that re-agent is employed.

§ 244. *Starch* is obtained from wheat flour; it is white, insipid, inodorous, and usually concrete; forms a sort of jelly with boiling water, from which the starch slowly separates, and falls down. Starch undergoes no change by long keeping in dry air.

§ 245. *Indigo* is the produce of the indigofera tinctoria, and other species of the indigo plants; it is obtained from the leaves. It is a fine light friable substance of a deep blue colour; it is not altered by exposure to the air.

§ 246. *Gluten* is obtained from wheat flour; it is grey, tenacious, ductile, and elastic; soon decomposes if kept moist in contact with the air, and emits an offensive odour, like that of putrid animal matter.

§ 247. *Pollenin* is obtained from the pollen of the pinus sylvestris; it is yellow, and has neither taste nor smell.

§ 248. *Vegetable fibrin* was obtained by Vauquelin from the juice of the papaw tree, (carica papaya); it has a greasy appearance, softens in the air, and becomes viscid, brown, and semi-transparent.

§ 249. *Fixed oils* are found in the seeds of plants, and in the pulp which surrounds the stone of some fruits, as the olive. They are fluid at moderate temperatures, but congeal at 32°, and some even above that temperature; when pure they are transparent, colourless, and almost without taste. They are lighter than water, and do not combine with it; boil at 600°; absorb oxygen by exposure to the air, and become rancid; they burn readily with flame. Fixed oils combine with several metallic oxides, and with sulphur. They also dissolve phosphorus, and the liquid is luminous when exposed to the air. They combine with mucilage.

§ 250. *Wax* is found on the surface of the leaves of some plants, as the myrica cerifera; it possesses all the properties of bees-wax, the subject of this section. Wax is white, insipid, and nearly inodorous; not altered in the air; melts at about 155°.

§ 251. *Volatile oils* are usually obtained by distillation from the flowers, fruit, stems, and indeed every part of aromatic plants, except the cotyledons of the seeds. They are as various as the plants which afford them; each is distinguished by a peculiar odour, derived from the peculiar essential oil it contains. Hence we must confine ourselves to a description of their general properties; an enumeration of each variety would be almost impossible. Some of the essential oils are contained in distinct vesicles, and may be obtained by mere pressure, such as those of the orange and lemon peel; they are in general lighter than water, a few only as the oil of cloves and cinnamon are heavier than that fluid; they are volatile at a temperature below that of boiling water; are generally thin fluids, sometimes viscid; some of them become solid at moderately low temperatures, others retain the liquid form at the most intense cold. When exposed to the air the essential oils gradually lose their smell, absorb oxygen, and become thick, and almost concrete, and an acid crystalline substance separates from them. They are more inflammable, and their combustion is more intense, than that of the fixed oils. They dissolve sulphur and phosphorus, and unite in small proportion with sugar and mucilage. The essential oils may be distinguished from the fixed, with which they are frequently adulterated, by their solubility in alcohol, and by their leaving no greasy stain on paper that has been wetted with them, after exposure to heat.

§ 252. *Camphor* was first carefully examined by Newmann, who shewed that its properties entitle it to be considered as a peculiar vegetable principle, and not either as a resin or volatile oil, with one or other of which it was usually classed. It is obtained from the laurus camphora; it is a white brittle substance, yet possessed of a certain degree of toughness; its taste is acrid, and odour peculiar; its volatility very great; it even evaporates entirely when freely exposed to the air: when sublimed in close vessels it condenses in hexagonal plates; from a solution in alcohol it separates in plumose crystals. Camphor takes fire readily, and even burns on water. A small piece of camphor laid on the surface of quite still water soon begins to contract a circular motion on its own axis, which gradually becomes more rapid till it turns with considerable velocity.

The same phenomena occur with benzoic acid and many other odorous substances under similar circumstances. (Nicholson's Journal, 8vo. vol. i. p. 51.)

§ 253. *Bird-lime* is both a natural and artificial product; the former is found on the epidermis of the robina viscosa, the latter is formed from the middle bark of the holly.

The colour of natural bird-lime is green; it is inodorous and insipid, very adhesive, and softens by the heat of the hand;—by a higher heat it melts, swells up, and burns with considerable flame. It does not become hard or brittle by exposure to the air. The properties of artificial bird-lime are very similar in colour, tenacity, &c.; it has besides a sour flavour, and reddens litmus; its taste is something like that of linseed oil.

§ 254. *Resins;* this is a very numerous class; in their general properties resins are distinguished by being brittle, slightly transparent, and usually of a yellowish colour. When pure, they are inodorous, with a rather acrid taste. They are all capable of becoming electric by friction, and exhibit negative electricity. They are heavier than water, but the specific gravity varies in different resins.

According to a table of ten species given by Thomson, from Brisson's and his own experiments, the lightest is that of elemi, which is 1.0182 and the heaviest that of labanum, which is 1.1862. The mean of the ten is 1.0772. Resins melt by heat, and burn with a strong yellow flame and much smoke.

§ 255. *Guaiacum* is obtained from the guaiacum officinale: we are indebted to Mr. Hatchett for demonstrating the peculiar nature of this substance, which previous to his experiment was considered as a resin. It was particularly examined by Mr. Brande. Guaiacum is solid and resembles resin in appearance. It becomes green by exposure to the light, but loses that colour when heated. It is almost insipid, but has a rather fragrant odour when pounded. It melts by heat; its specific gravity is 1.2289.

§ 256. *Balsams*, in the present acceptation of the term, comprehend two classes of substances, the one fluid, the other solid and friable. The name was first applied to the substance called Balm of Gilead, obtained from the amyris gileadensis. It was afterwards used to denote those resinous matters which afford benzoic acid when heated, and this property is one of the chief characteristics by which balsams are distinguished from resins. They have frequently been regarded as compounds of resins and benzoic acid, but the latter according to Hatchett is more probably an artificial product.

§ 257. *Gum Resins* are exudations from certain plants, which become hard by exposure to the air; they are usually nearly opaque, brittle, and have sometimes a fatty appearance. They soften by heat, and swell up and burn with flame.

They are very odorous, and have a disagreeable acrid flavour. They are generally heavier than resins. Gum resins, as the name implies, have been considered as compounds of gum and resin; they contain a volatile substance, something between essential oil and resin, to which the milkiness of the compound they form with water is owing; the other constituent possesses the properties of extractive rather than those of gum.

§ 258. *Caoutchouc*, commonly known by the name of Indian or Elastic Rubber, is obtained from a milky juice, which exudes from the hœvea caoutchouc and other trees of Brazil and the East Indies, when punctured: the juice thickens by exposure to the air, and affords, the caoutchouc. Chlorine causes the immediate precipitation of caoutchouc from the milky juice, and when confined in a vessel filled with common air, the oxygen gradually disappears, and a pellicle of caoutchouc forms on the surface of the juice; hence its inspissation is evidently connected with its absorption of oxygen. Caoutchouc, when pure, is white, insipid and inodorous, soft, pliable and extremely elastic; when suddenly and forcibly extended there is a very sensible evolution of heat, but the caoutchouc immediately recovers its former temperature and dimensions as soon as the force is removed. It suffers no change by exposure to the air, melts readily by heat, and loses its former properties; it burns with a bright flame, giving out a disagreeable smell, and when distilled it yields ammonia. In addition to the few substances mentioned in the table as capable of dissolving caoutchouc, may be added rectified petroleum, which according to Fabroni, leaves it unaltered, when driven off again by evaporation.

From its perfect insolubility in water, caoutchouc has lately been substituted for gums in the manufacture of hats: those known by the name of Collinson's water proof hats, are, I am informed, prepared with this substance.

§ 259. *Suber*, as its name denotes, is a peculiar vegetable principle contained in the bark of the cork tree (quercus suber). It is light, soft and elastic, burns with a bright flame and yields ammonia by distillation. It appears that suber is not the produce merely of the cork tree, since Professor Linck obtained suberic acid, by the action of nitric acid, on the pith of elder, and on paper. He conceives it to be a peculiar characteristic of vegetable membrane, to furnish suberic acid.

§ 260. *Medulla* was obtained by Dr. John, from the pith of the sunflower (helianthus annuus) and other plants. It is insipid and inodorous, has a porous texture, and affords ammonia by distillation.

§ 261. *Wood*, or *woody fibre*, may be considered as the skeleton of trees, and of the greater number of plants in general.

It is the residuum after every thing soluble in water and alcohol has been removed by the successive action of these agents. Its texture is fibrous: the fibres are arranged longitudinally, and may easily be separated from each other. It is destitute of smell and taste, and suffers no change by exposure to the air. It does not melt by heat, but becomes black and exhales acrid fumes; by distillation it yields an acid liquor, which was at first considered peculiar, and called the pyroligneous acid, but subsequent experiments have proved it to be merely acetous acid mixed with empyreumatic oil. This acid is obtained in large quantities in the preparation of charcoal for the manufacture of gunpowder, and has lately been purified and made applicable to all the purposes for which acetic acid is employed; see Thenard, vol. iii. p. 60, for the method of purifying pyroligneous acid.

§ 262. *Fungin* is to the fungi, what woody fibre is to trees. It is white, soft, and insipid, burns readily when dried, and leaves a residuum chiefly consisting of phosphate of lime. It yields by distillation empyreumatic oil, ammonia, and acetate of ammonia.

§ 263. The foreign substances found in plants, which rather belong to the mineral than the vegetable kingdom, have been described in the former parts of this volume. It is merely necessary in this place to enumerate them.

They consist of the phosphoric, hydrochloric, sulphuric, nitric, and carbonic acids, (generally in combination with bases, forming neutral salts;) potassa and soda, silica, lime, magnesia and alumina. Minute portions of iron and manganese have also been obtained from the ashes of some vegetables.

A method has lately been announced by M. Peschier of Geneva, for discovering potassa in vegetables, without the necessity of first reducing the plant to ashes. It consists in boiling vegetable juice with an excess of pure magnesia, and separating the insoluble magnesian salt, generally an oxalate or a tartrate, by the filter. The potassa remains in solution in the clear liquor in the state of subcarbonate.

Magnesia being incapable of decomposing the sulphate and nitrate of potassa, the alkali cannot be detected by this process in plants in which it exists in either of those forms, as is the case in the common borage (borago officinalis), whose juice does not redden infusion of litmus; but it is seldom found in vegetables in that state of combination. (An. de Chimie, vol. ix. p. 99, new series.)

Such are the general characters of the most important of the proximate vegetable principles, and it is essentially necessary to the young chemist, who would accomplish himself in this species of analysis, to become well acquainted with them by study and experiment. It is not possible in the present state of the science, to give any general rules that may be applicable to every case. This branch of it is yet in its infancy, and much remains to be done, not only to render it perfect, but even to place it on the same level that the analysis of inorganic matter has already attained. It is not perhaps to be expected that it will ever rival the accuracy of that department of chemistry, but as its importance is daily more appreciated, so it is evidently making rapid strides of improvement, witness the recent discoveries of morphia, meconic acid, picrotoxine, and several other substances.

With respect to a general formula, no precise one, as I have said already, can be laid down; but usually in the examination of a vegetable substance, it is first submitted to the action of water, and when all the matter soluble in that fluid is removed, it is treated successively with alcohol, ether, acids, (chiefly the acetic, or diluted nitric) and a solution of potassa or soda, and the substances separated by each of these solvents, must be then submitted to rigorous and careful examination. Their respective natures will be ascertained, by comparing the results on the application of appropriate tests, with the characters of the various substances detailed in the preceding pages.

§ 264. I subjoin Mr. Hatchett's examination of shell-lac, as an accomplished specimen of proximate analysis of a vegetable substance, which will be highly useful to the young student.

The paper from which it is extracted, is printed in the Transactions of the Royal Society for 1804, p. 191.

An attentive perusal of this essay (as well as of Mr. Hatchett's other labours) cannot be too strongly recommended, whether as a comprehensive history of the subject of which it treats, or as an instructive example of philosophical investigation, equally admirable for its ingenuity, and the clearness, accuracy, and precision, with which the results are detailed.

"A. 500 grains of shell-lac were first treated with successive portions of boiling distilled water, till it ceased to be coloured; the whole of the aqueous solution was then evaporated, and left a deep red substance, which possessed the general properties of vegetable extract, and weighed 2.50 grains.

B. The 497.50 grains which remained were then digested with different portions of cold alcohol, until this ceased to produce any effect; the resin which was thus separated amounted to 403.50 grains.

C. As the shell-lac had not been reduced into powder, but only into small fragments, these were become white and elastic, and when dry were brittle, and of a pale brown colour; the whole then weighed 94 grains.

D. These 94 grains were digested in diluted muriatic acid; and the acid after being saturated with solution of carbonate of potash, afforded a flocculent precipitate, (resembling that obtained from solutions of vegetable gluten,) which, when dry, weighed 5 grains.

E. Alcohol acted but feebly on the residuum; it was therefore put into a matrass, with three ounces of acetic acid, and was suffered to digest without heat during six days, the vessel being at times gently shaken; the acid thus assumed a pale brown colour, and was very turbid. The whole was then added to half a pint of alcohol, and was digested in a sand bath; by which a brownish tincture was formed, and at the same time a quantity of a whitish flocculent substance was deposited, which being collected, well washed with alcohol on a filter, and dried, weighed 20 grains.

This substance was white, light, and flaky, and when rubbed by the nail, it became glossy like wax; it also easily melted, was absorbed by heated paper, and when placed on a coal or hot iron, emitted a smoke, the odour of which very much resembled that of wax, or rather spermaceti.

F. The solution formed by acetic acid and alcohol being filtrated was poured into distilled water, which immediately became milky, and being heated, the greater part of the resin which had been dissolved assumed a curdy form, and was partly separated by a filter, and partly by distilling off the liquor; this portion of resin amounted to 51 grains.

G. The filtrated liquor, from which this resin had been separated, was saturated with a solution of carbonate of potash, and being heated, a second precipitate of gluten was obtained, which, when well dried, weighed 9 grains.

The 500 grains of shell-lac thus yielded,

A.	Extract	2.50 grains.
B. F.	Resin	454.50
D. G.	Vegetable gluten	14.
E.	Wax	20.
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The shell-lac being in small fragments, and not in the state of a powder, considerably facilitated the decantation of the solution in alcohol from the residuum; and although in this last, a portion of the resin was protected from the action of the alcohol by being enveloped in the gluten and wax, yet, by the assistance of acetic acid, the remainder of the resin, as well as the whole of the gluten, was dissolved, the wax was obtained in a pure state, and a separation of the resin from the gluten was afterwards easily effected, by the method which has been described. As therefore acetic acid is capable of dissolving resin, gluten, and many other of the vegetable principles, it certainly may be regarded as a very useful solvent, in the analysis of bodies appertaining to the vegetable kingdom."

DIVISION THE THIRD.

Of the Proximate Principles of Animal Substances.

§ 265. *Gelatine* is usually prepared from the skin of animals. Common glue is gelatine contaminated with impurities, to which it owes its colour. Isinglass is gelatine nearly in a state of purity. Gelatine, when quite pure is semitransparent, and colourless, hard, brittle, and breaks with a glassy fracture: it has scarcely any taste or smell, and is heavier than water. It swells up when put into water, but does not readily dissolve; but after it has been softened by this process it is readily soluble in warm water. Dry gelatine suffers no change by keeping, but it soon putrifies, when in a moist state; when heated it curls up like horn, and becomes black.

§ 266. *Albumen* is the most frequent of the proximate animal principles. The white of an egg, which is the substance whose properties are detailed in this section, is almost pure albumen; it however contains besides some mucus, soda, (whence it turns syrup of violets green) and sulphur.

Albumen is heavier than water. One of the principal characters of albumen is its property of coagulating by heat: this effect takes place at the temperature of about 160°. It suffers no change either in volume or weight by coagulation; but it becomes insoluble in water, and is altered in respect to its flavour. If previously diluted with a large quantity of water, it ceases to be coagulable, which according to Dr. Thomson is owing merely to the separation of its particles to a certain distance from each other; for when they are made to approach again by evaporating the fluid, the albumen coagulates as before.

Dr. Thomson attributes the coagulation of albumen to the separation of the alkali, as silica gelatinizes when hydrochloric acid is added to a solution of silicated potassa. In its natural state albumen is combined with water and soda, and the compound remains fluid, because the attractive force of the particles of the albumen for each other is exactly balanced by the chemical affinities between them and the other substances; but according to Thomson, when heat is applied, the expansion of the water diminishes that affinity, by separating its particles and those of the soda to a greater distance, so that the attractive force of the particles of albumen prevails over the antagonist power, and they unite into one solid mass.

Mr. Brande, subjected albumen to the action of voltaic electricity; the alkali separated at the negative pole and the albumen coagulated. Voltaic electricity may thus be made a very delicate test of the presence of albumen. In its uncoagulated state, albumen is a glary, almost insipid, inodorous liquid, very subject to putrefaction, and more readily so when dissolved in water than when in its natural state.

Of a great number of metallic salts which he tried, Dr. Thomson found that almost all, except the arseniate of cobalt, precipitated albumen from its solution in water, when the oxide was combined with an acid; but if held in solution by an alkali or an earth, the albumen was not thrown down. According to Dr. Bostock, a saturated solution of corrosive sublimate detects albumen when dissolved in 2000 times its weight of water. This test may also be employed to ascertain the quantity of albumen in an animal fluid; it is to be added in excess, and the mixture heated; a precipitate falls down which when collected and carefully dried contains about 78 per cent. of albumen. (Nicholson's Journal, vol. xiv. p. 142.) From the experiments of the same intelligent philosopher, it appears that water, containing only $\frac{1}{1000}$th of its weight of albumen in solution, is rendered sensibly opaque by boiling.

§ 267. *Coagulated Albumen.*—It is necessary to mention albumen also in this state, since its characters differ materially from those of uncoagulated albumen. We suppose it to be coagulated by alcohol. It is solid, white, insipid, inodorous, and heavier than water: it has no effect on syrup of violets; by heat it affords a large quantity of subcarbonate of ammonia, and a bulky ash; it resembles fibrine in its action on acids, alkalies, alcohol, ether, and water, except that it is less soluble than that substance in acetic acid and ammonia, and much more so in potassa and soda.

They are distinguished by acetic acid rendering an alkaline solution of fibrine turbid, but on a similar solution of albumen it has no effect.

§ 268. *Fibrin* is the most abundant principle in animal substances; it is obtained from the red clot of recent blood, and from muscle; it is heavier than water, white, insipid, inodorous, soft, elastic, and similar to vegetable gluten; its colour becomes darker by drying. It is not at all altered by exposure to air when dry, and not readily when kept in water. Azote is disengaged from fibrin by the action of acetic acid. By heat it contracts suddenly, moves like horn, and exhales the smell of burning animal matter; by a higher heat it melts.

§ 269. *Colouring matter of the blood.* The animal nature of this principle was first pointed out by Dr. Wells, but Fourcroy and Vauquelin considered it to be owing to subphosphate of iron, which according to them is held in solution in blood, and imparts to it its red colour. Mr. Brande, in 1812, demonstrated the fallacy of this opinion, and proved, by satisfactory experiments, its title to be considered as a peculiar animal principle.

The subsequent experiments of M. Vauquelin have confirmed Brande's results. It is obtained from the red coagulum of recent venous blood. When dry it appears black, but diffused through water, it has a wine-red colour: it is insipid and inodorous; it is not altered either in form or colour by a moderate heat.

§ 270. *Mucus* is obtained from saliva, which by evaporation to dryness, and solution in water, is, according to Dr. Bostock, almost pure mucus. He also obtained it by evaporating the liquid in which an oyster had been macerated. It resembles gum arabic in its general appearance, but is more opaque; it is almost insipid, does not coagulate by heat, nor gelatinize by evaporation. By heat it assumes the appearance of horn.

§ 271. *Osmazome* is obtained from muscle; it has a brownish yellow colour, and the flavour and smell of broth; it swells up when heated, and is decomposed. According to Dr. Thomson, it is very doubtful if osmazome be any thing but fibrin, slightly altered by solution in water.

§ 272. *Picromel* is obtained from bile; it is heavier than water, its colour is greenish yellow, it has an intensely bitter taste, which is succeeded by a slight degree of sweetness. It does not yield ammonia by distillation.

§ 273. *Urea* is obtained from urine. It usually crystallizes in plates which cross each other in all directions, and have a yellowish tinge; but, when perfectly pure, urea is white, semi-transparent, and the form of its crystals is a tetrahedral, or hexahedral prism. It is heavier than water; its odour is fetid, something like garlic; its flavour acrid; it deliquesces in the air; by heat urea melts, swells up, and is dissipated, exhaling an intolerable stench. Its solution in water decomposes by long keeping; its decomposition is accelerated by the addition of a little gelatine. A solution of urea does not decompose any of the salts: mixed with hydrochlorate of soda it occasions it to crystallize in octohedra, and hydrochlorate of ammonia in cubes.

§ 274. *Sugar of milk* is white, sweet, and inodorous; it crystallizes in regular parallelopipedons, terminated by tetrahedral pyramids; it is heavier than water. When burnt it exhales the odour of caromel (*a*) and resembles burning sugar; it yields by distillation the same products as sugar.

There are two other saccharine principles belonging to the animal kingdom:—*honey* (though perhaps this is rather a vegetable compound) and the *sugar of diabetic urine*. They are both more analogous to common sugar than to the sugar of milk, since they yield oxalic acid by the action of nitric acid, and are susceptible of the vinous fermentation, which, according to Bucholz, is not the case with sugar of

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(*a*) A French term to express the peculiar odour given off by burning sugar.

milk; moreover the acid formed by it with nitric acid is the saclactic.

§ 275. *Cantharadin* is the name given by Thomson to the blistering matter in Spanish flies, from which it is obtained; it has the form of small crystalline plates with a shining micaceous appearance.

§ 276. *Cochenelin* is the name given by Dr. John to the red colouring matter of the cochineal insect, (Coccus cacti) from which it has been lately obtained pure by M. M. Pelletier and Caventou. It is a very brilliant purple red powder, with a granular crystalline appearance; it is not altered in the air, nor sensibly deliquescent; it melts at about 120°; by a higher heat it swells up and is decomposed. Lime water gives a violet precipitate with cochenelin; fresh precipitated alumina carries down all its colouring matter, and forms a fine red lake. Barya and strontia act like the alkalies on it, and give no precipitate with cochenelin, but alter its properties; nitrate of silver has no decided action on it: salts of copper give no precipitate, but the colour becomes violet. The earthy and alkaline salts affect the colour of cochenelin, making it pass to violet or crimson, but occasion no precipitate. The vegetable and animal acids change it to yellowish red, but throw nothing down from its solution either in water or alcohol.

M. M. Pelletier and Caventou propose to call this substance *carmine*; if we adopt the term, its termination should be altered to avoid confounding the pure colouring matter with the pigment in common use. It may be called *carmina*, a more harmonious name than cochenelin. (Ann. de Chimie, vol. viii. p. 250.)

§ 277. *Fat.* This substance is one of the fixed oils, of which the animal kingdom affords several varieties. Their general properties are very analogous, those of *fat* may be considered as more or less possessed by each individual of the class. The consistence of *fat* varies from the hardness of tallow to the softness of hog's lard. The latter melts at 97°, the fat of meat at 127°; its decomposition commences at about 400°, when it emits a white smoke, and becomes blackish. If it be cooled at this period it is more solid and brittle than at first. By distillation, fat affords water, a white oil, hydruretted carbon and carbonic acid gases, which, according to Thomson "have a most abominable odour, so detestable and powerful that it is almost impossible to endure them," owing to some empyreumatic oil formed in the process. Sulphur and phosphorus are soluble in small quantity in fat.

§ 278. Stearin (from στεαρ, tallow.) It appears from the experiment of Chevreul, that fat consists principally of two distinct substances, which, from the process used by Braconnot to separate them, (simple pressure and absorption of the most fluid) are rather mechanically mixed together than chemically united. They are both obtained from hog's lard.

Stearin is white, brittle, and in appearance somewhat resembles wax. It is inodorous and insipid, melts at 109°, but the point of fusion varies according to the fat from which it has been obtained; that from human tallow requires a temperature of 120°.

§ 279. Elain (from ελαιον, oil) is the name given to the other substance contained in fat. It is very similar to vegetable oil in appearance, is colourless and inodorous if quite pure, but it is usually contaminated with admixture of some foreign bodies; it is liquid at 59°. In hog's lard, according to Braconnot's experiments, the proportion of elain is to that of stearin as 62 : 38.

§ 280. *Ambergris* is one of the substances resembling resins, which are found in various animal bodies. The principal, besides ambergris, are musk, civet and castor. I shall detail only the properties of ambergris, which when pure is lighter than water, soft, of an ash-grey colour, with brownish yellow and white streaks. It has a pleasant smell, but no taste; it melts at 122°, and is completely volatilized at 212°. By distillation it yields a whitish acid liquid, and a volatile oil.

DIVISION THE FOURTH.

Animal Acids.

§ 281. *Uric acid* is obtained from urinary calculi; it is a white, insipid, inodorous powder, reddens vegetable blues, and is soluble in 1720 parts of water at the common temperature, or in 1150, at 212°. The hot solution deposits small crystals, as it cools. It decomposes the alkaline hydrosulphurets, but has no action on alkaline carbonates. The urates are in appearance very similar to the uncombined acid, insipid, and suffer no change by exposure to the air. They are sparingly soluble in water. The suburates (those which contain an excess of base) are more soluble than the urates.

The neutral salts are decomposed by all the acids except the carbonic and hydrocyanic, and the uric acid is precipitated. If either of the two weak acids just named be added to a solution of a suburate, or a small portion of a stronger acid, merely sufficient to saturate the excess of base, the precipitate consists of the neutral salt.

Uric acid is decomposed by heat, affording, besides the usual products from animal matter, a solid substance, which sublimes, and condenses in the upper part of the apparatus. This substance is at first brownish, but by a second sublimation, loses its colour, and becomes white; it is inodorous, has a subacid flavour, reddens litmus, and dissolves readily in boiling water, and sparingly in alcohol.

The aqueous solution does not precipitate lime-water or solutions of the earthy salts, nor decompose the salts of gold, platina, copper, tin, or iron. It does not give any red colour by the action of nitric acid, nor is its solution in alkalies precipitated by acids.

§ 282. *Rosacic acid.* The substance which separates from the urine of feverish patients, and known to medical men by the name of *lateritious sediment*, is supposed by Proust, to consist of a mixture of uric acid, and phosphate of lime, with a peculiar matter which he has called rosacic acid, from its colour. According to him, it is distinguished from uric acid, by its greater solubility in hot water, by not crystallizing so readily, and by its action on the salts of gold, with which it gives a violet-coloured precipitate.

§ 283. *Purpuric Acid.*—In the column of acids in the annexed tables, it will be seen that a pink colour is produced by the action of nitric acid on the uric. Dr. Prout has lately shewn that that substance is a compound of ammonia, with a peculiar acid, which, at the suggestion of Dr. Wollaston, he has named the Purpuric, from its remarkable property of forming salts with most bases, of a red or purple colour.

It is formed by the decomposition of uric acid by nitric acid, and a similar effect is produced by chlorine.

and iodine, but in a much less degree by the latter. I shall state the mode of obtaining it (the subject being new and interesting) nearly in the words of Dr. Prout, as given in his valuable paper in the Philosophical Transactions.

"The acid principle may be obtained by digesting pure lithic (uric) acid in dilute nitric acid; an effervescence takes place, and the lithic acid is dissolved. The excess of nitric acid is then to be neutralized with ammonia, and the whole slowly concentrated by evaporation. As the evaporation proceeds, the colour of the solution gradually becomes of a deeper purple, and dark red granular crystals (sometimes of a greenish hue externally) soon begin to separate in abundance. These crystals are a compound of ammonia, with the acid principle in question: they are to be dissolved in a solution of caustic potash, and heat applied to the solution, till the red colour entirely disappears. This alkaline solution is then to be gradually dropped into dilute sulphuric acid, which unites to the potash, and leaves the acid principle in a state of purity." Purpuric acid is a very fine powder, of a cream colour, without either smell or taste; it is heavier than water; by slow evaporation it sometimes assumes the form of thin pearly scales. It does not sensibly affect litmus paper, nor deliquesce in the air, but gradually becomes purplish; it neither melts nor sublimes by heat. It decomposes the alkaline carbonates by heat. Purpurate of ammonia crystallizes in quadrangular prisms, which, when viewed by transmitted light, are transparent and of a deep garnet red colour; but by reflected light, their two broadest opposite faces appear of a brilliant green, closely resembling the wings of some of the beetle tribe, as for example the Cetonia aurata, while their other two opposite faces appear of a dull reddish brown colour; or, if the light be very strong, slightly green. This peculiarity seems to be possessed, in a greater or less degree, by all the other alkaline and perhaps earthy purpurates. Purpurate of ammonia dissolves in 1500 parts of water at 60°, but in boiling water it is much more soluble; the solution is of a beautiful deep carmine. It is little if at all soluble in pure alcohol and ether. I subjoin the effect of a solution of purpurate of ammonia, on solutions of the metallic salts, not mentioned in the table.

Purpurate of gold	solution yellowish; no precipitate.
platina	yellowish scarlet; ditto.
silver	deep purple precipitate.
zinc	solution & precipitate beautiful gold yellow.
copper	ditto bright yellowish; no precipitate.
nickel	ditto greenish; ditto ditto.
cobalt	solution pale scarlet; reddish granular crystals.

Philosophical Trans. 1818. p. 240.

§ 284. *Amniotic acid* is obtained from the liquor of the amnios of the cow, by slow evaporation, in the form of white brilliant crystals of a slightly sour taste. Its solution reddens vegetable blues, and decomposes the alkaline carbonates by heat. When exposed to heat the amniotic acid froths up, and exhales an odour of ammonia, and hydrocyanic acid.

§ 285. *Margaric acid* was obtained from hog's lard by Chevreul in 1813, by uniting that substance with potassa, and submitting the pearly scales which are deposited when the compound is mixed with water, to the action of dilute hydrochloric acid, which separates the alkali, and leaves the margaric acid free. Its colour is pearl white; it is insipid, has a slight smell something like that of wax, floats on water, melts at a temperature of 134°, and crystallizes in very white brilliant needles as it cools. It reddens vegetable blue colours. By distillation a part of the acid comes over unaltered, and another part forms a yellow concrete butyraceous substance, differing in its properties from margaric acid, and incapable of combining with potassa. Very little gas or charcoal are produced in the process.

§ 286. *Oleic acid* was obtained by Chevreul from the soluble portion of the soap formed with hog's lard and potassa.

It is an oily, inodorous, colourless fluid; but, if impure, frequently rancid and brown. It is lighter than water, and becomes solid, between 33° and 44°. When congealed, it forms needle crystals. It reddens vegetable blues very readily.

§ 287. *Formic acid*, or the acid obtained from infusion of ants, seems to have but a very doubtful claim to be considered as a peculiar substance. Chemists have been much divided in opinion respecting it. Deyeux supposed it analogous to the acetic, and Fourcroy and Vauquelin pronounced it a mixture of acetic and malic acids. Suersen, Gehlen and Berzelius, on the contrary, conclude that it possesses peculiar properties. I have thought it right therefore not to omit altogether, though I have not inserted it in the annexed tables. According to Gehlen's experiments, as stated by Dr. Thomson in the fifth volume of the Annals of Philosophy, it has the following properties; an acid and peculiar taste and smell, quite different from that of acetic acid; when cooled down sufficiently, it becomes solid, but does not crystallize. Its specific gravity is 1.1168, when diluted with an equal weight of water 1.06, and with twice its weight 1.0296. The formates of copper and barya differ from the acetates of the same bases in colour, solubility, form of crystals, and all their other properties.

§ 288. *Lactic acid*, like the formic, has been the subject of very different opinions. It was discovered by Scheele in sour milk, who considered it as a peculiar acid, a conclusion which was denied by Bouillon La Grange, Thenard, Fourcroy, and Vauquelin. Berzelius has more lately submitted it to a fresh examination, and confirms the opinion of Scheele.

The process by which Berzelius obtained it in a state which he considers pure, is singularly complicated, and justifies the remark of Dr. Murray, "that some doubts may yet remain on the subject." The opinions however of two such men as Scheele and Berzelius, are not to be rejected without the clearest evidence of their fallacy, even though opposed to the inferences of the illustrious French Philosophers named above.

The following are the properties of lactic acid according to Berzelius. It has a brown yellow colour, and a sharp sour taste, which is much weakened by diluting it with water. It is inodorous whilst cold, but gives off an acid smell by heat, perfectly distinct from the acetic, but similar to that of sublimed oxalic acid; it is uncrystallizable, and dries into a thick, smooth, slightly deliquescent varnish. It boils by heat and is decomposed, but evolves no odour of animal matter. Its alkaline, earthy and metallic salts, are soluble in alcohol, and generally have no tendency to crystallize, but dry into a mass like gum, which slowly becomes moist in the air.

The solution of lactate of silver is light yellow inclining to green. Protolactate of mercury, light yellow, perlactate red; lactate of lead forms crystalline grains of a grey colour; lactate of iron is red brown; lactate of copper varies from blue to green and dark blue; it does not crystallize. (Philosophical Magazine, vol. 41. page 241.)

§ 289. *Hydrocyanic* or *Prussic acid.*—This acid exists ready formed in the leaves of the laurocerasus, in peach blossoms, bitter almonds, and several other vegetables, and might with propriety have been described with the proximate vegetable principles; indeed, as proximate principles are our immediate object, it ought rather perhaps to be associated with the vegetable acids than occupy this place; strictly speaking, those only can be considered as proximate principles which actually form a part of living vegetable or animal bodies, and are obtained by processes so simple, as to leave little reason to suspect that their natures are thereby altered; for all the rest are the products of operations, natural or artificial, which the organized matter undergoes after it is dead. But if this were insisted on, many substances very interesting to the chemist would be struck out of this class, and a new one formed for them, which would produce greater inconvenience than that it was intended to remove, for, to create new subdivisions unnecessarily, is rather to introduce confusion than to avoid it. I have therefore inserted Daniell's lampic acid, and other bodies artificially produced from vegetable substances, amongst the proximate vegetable principles, as I do here the hydrocyanic amongst the animal.

The properties and analogies of cyanogen have been already given (§ 12 L and § 37 H.) Hydrocyanic acid was first obtained from blood, but the processes then employed did not afford it pure, nor was it known in that state, nor its composition well understood prior to the experiments of M. Gay Lussac in 1815, to whom we are indebted for a correct acquaintance with this interesting body.

Hydrocyanic acid is a colourless transparent liquid, with a strong smell, resembling that of peach blossoms. Its taste is at first cool, but soon becomes sharp and irritating; it excites a burning sensation in the mouth, and acts as a most violent poison. In all experiments on this substance, the operator should avoid inhaling its fumes with the utmost care. It reddens litmus faintly, boils at the temperature of 80°, and becomes solid at about that of 5°. If a few drops of the acid be let fall on paper, the cold which is produced by the evaporation of one part is sufficient to congeal the other, even at the temperature of 68°. It is very difficult to keep it in the best stopped vessels many days without its decomposing. It takes fire in the air by the approach of a burning body. It does not readily unite with water, but alcohol dissolves it with great facility. Iodine occasions no change in the vapour of hydrocyanic acid; chlorine decomposes it, disengages its hydrogen, and forms a peculiar acid, the chlorocyanic, with the cyanogen.

If the vapour of hydrocyanic acid be detonated with oxygen gas, a quantity of oxygen disappears equal to 1.25 of the volume of vapour employed. Suppose 100 volumes of the gas be operated on, the result will be 100 of carbonic acid, and 50 of azote. It will be remembered that carbonic acid is composed of one volume of vapour of carbon and one of oxygen, condensed into one volume. Therefore the 100 volumes of carbonic acid produced by the detonation indicate an equal quantity of oxygen; the remaining 25 volumes must have combined with hydrogen to form water. According to this experiment, hydrocyanic acid is composed of one volume of vapour of carbon, half a volume of azote, and half a volume of hydrogen, condensed into one volume. It is necessary that the oxygen be in excess to ensure the complete combustion of the acid vapour, and also that the temperature be sufficiently high to prevent any portion of it from being condensed into the liquid state. Gay Lussac operated at the temperature of 71°.

The preceding result is confirmed by comparing the weight of hydrocyanic vapour with those of its elements.

Density of a volume of vapour of carbon = 0.4173.
. . . . half a volume of azote . . = 0.4843.
. . . . half a volume of hydrogen . = 0.0368.

Density of a volume of hydrocyanic vapour = 0.9384.

Gay Lussac found it by direct experiment . 0.9476.

It has been mentioned (§ 37, H.) that the specific gravity of cyanogen is 1.8064; the half of which (.9032) almost exactly corresponds with the weight of a volume of carbon, and half a volume of azote. It is clear from these results, that hydrocyanic acid consists of half a volume of cyanogen and half a volume of hydrogen, and that they unite without condensation.

This is further confirmed by the action of potassium. When that metal is heated in hydrocyanic acid, the vapour disappears and is replaced by half its volume of hydrogen, and the potassium is converted into a grey fusible mass. When this is thrown into water, a portion of the fluid is decomposed without effervescence, and is found to contain a solution of hydrocyanate, or prussiate of potassa. The action is obvious. Potassium absorbs the cyanogen, and liberates its hydrogen; by the decomposition of the water, the metal combining with oxygen is converted into potassa, whilst its hydrogen unites to the cyanogen, and reproduces hydrocyanic acid.

The hydrocyanate of potassa, formed in the experiment just stated, is not identical with the salt commonly known by the name of prussiate of potash, and so important in chemical analysis for the indications it affords of the presence of metallic oxides. Pure hydrocyanate of potassa is of so little permanency that it cannot be long exposed to the atmosphere without undergoing decomposition. But if potassa and Prussian blue be boiled together, we obtain a compound not only permanent in the air, but one whose acid is not easily displaced, even by the strongest mineral acids. This salt was formerly called the triple prussiate of potash and iron, for it was soon discovered that iron entered essentially into its composition, though its presence could not be detected by any of the usual tests for that metal. Mr. Porrett published, in 1814, an elaborate and able series of experiments on this subject, in the course of which he found that when the triple prussiate is submitted to the action of voltaic electricity, the alkali goes to the negative pole, and the acid and iron, in the state of protoxide, to the positive: whence he concludes, that it forms a component part of the acid itself, and since its other elements are carbon, hydrogen, and azote, he proposed for it the name of ferruretted chyazic acid; derived from the initials of the three constituents of hydrocyanic acid. Dr. Thomson, as I have mentioned before, (note 40, A.) considers it to be a compound of cyanogen and metallic iron. The effect of the alkaline salt formed with this acid, is very different from that of the simple hydrocyanate of potassa, on metallic solutions, as will be seen by the following table of the colours of the precipitates produced by each in solutions of metallic salts, copied from the third volume of Thenard's Treatise, page 530, and alluded to in the note mentioned above.

TABLE

OF THE COLOURS OF THE PRECIPITATES THROWN DOWN

From solutions of	By ferro-hydro-cyanate of potassa.	By simple hydro-cyanate (a).
Manganese	white	dirty yellow.
Protoxide of iron	white, copious	orange, copious.
Deutoxide of iron	clear blue, copious	blue green, copious.
Tritoxide of iron	deep blue, copious	almost imperceptible.
Tin	white	white.
Zinc	ditto	ditto.
Antimony	ditto	ditto.
Uranium	blood-colour	yellow white.
Cerium	white	
Cobalt	grass-green	
Titanium	red	
Bismuth	white	white.
Protoxide of copper	ditto	ditto.
Deutoxide of copper	crimson	yellow.
Nickel	apple-green	yellow white.
Lead	white	
Deutoxide of mercury	ditto	yellow.
Silver	white. It turns blue in the air.	white. Soluble in an excess of prussiate.
Palladium	olive	
Rhodium		
Platina		
Gold	white	white. It becomes a beautiful yellow.

(*a*) Many of the precipitates formed by the simple hydro-cyanate, are perhaps merely oxides; for these precipitates take place with a disengagement of prussic acid, and are of the same colour as those formed by the alkalies.

I subjoin a short detail of the properties of the three remaining acids, formed by the combination of cyanogen with chlorine, with sulphur, and with iron.

§ 290. *Chlorocyanic acid* was first observed by Berthollet, and called by him "oxyprussic acid."

Gay Lussac in 1815, pointed out its true nature, and gave it its present name.

Chlorocyanic acid is a colourless liquid, with a very strong and peculiar odour; it reddens litmus: its vapour is not inflammable, and occasions no detonation with oxygen or hydrogen. Its density as determined by calcination is 2.111. Its solution gives no precipitate with nitrate of silver, or barya water. It is readily absorbed by the alkalies, but they must be in excess to destroy its odour entirely: when this compound is acted on by an acid, carbonic acid is given off, with considerable effervescence, and an excess of lime being added to the acid solution, ammonia is abundantly evolved. The solution also now precipitates nitrate of silver, forming chloride of silver and consequently contains chlorine or hydrochloric acid.

M. Gay Lussac attempted the analysis of chlorocyanic acid, by detonation with oxygen, adding a little hydrogen to render the mixture inflammable. The vapour was previously mixed with carbonic acid, for when pure, it is condensed at a temperature between 60° and 70°, under the mean atmospheric pressure. A volume of the vapour, gave an equal volume of carbonic acid and half a volume of azote, and no water was formed, except that which arose from the combustion of the hydrogen, previously added. But it also contains chlorine. Now when chlorocyanic acid is acted on by potassa and an acid, the same quantity of carbonic acid is evolved, as is produced by detonation with oxygen, and, as already mentioned, ammonia is also generated. Since no water results from the combustion of the vapour with oxygen, but only carbonic acid, no hydrocyanic acid can be produced, when the chlorocyanic is decomposed by the alkali and acid, but the chlorine on its separation from the azote and carbon combines with the alkali, forming a chloride or a hydrochlorate, no matter which. Water is decomposed by the successive action of the alkali and acid, and as a volume of carbonic acid is formed, it follows that a volume of oxygen, and consequently two of hydrogen, have been afforded by the water. Since chlorocyanic acid gives half a volume of azote, when detonated with oxygen, and ammonia is formed by the other mode of decomposition, it follows that one volume and a half of the hydrogen of the water has been employed, in producing the volatile alkali, and the remaining half volume must have combined with the chlorine. But hydrochloric acid consists of equal volumes of chlorine and hydrogen: consequently the chlorine in a volume of chlorocyanic acid amounts to half a volume.

Thus the constitution of the vapour is
1 volume of vapour of carbon
½ a volume of azote
and ½ a volume of chlorine.

When chlorocyanic acid is heated with antimony, in a small glass retort, over a spirit lamp, the bulk of the acid gradually diminishes, chloride of antimony is formed, and when the operation is terminated, half a volume of cyanogen remains: but cyanogen contains two volumes of the vapour of carbon and one of azote, condensed into one volume. This result confirms the inference drawn from the former experiments, and it is further established, by comparing the densities of chlorocyanic acid, chlorine and cyanogen.

Density of chlorine	2.4713
cyanogen	1.8033
	4.2746

The half of which is 2.1373. Gay Lussac found the density of chlorocyanic acid, by calculation, to be 2.111.

Consequently, it is composed of equal volumes of cyanogen and chlorine, and they unite without condensation. (Annales de Chimie, vol. xcv. p. 210.)

§ 291. *Sulphocyanic acid* was discovered by Mr. Porrett in 1808. Conceiving it to contain less oxygen than prussic acid, he first called it prussous acid, but in 1814, he published a more detailed account of its properties under the name of sulphuretted chyazic acid.

Sulphocyanic acid is a transparent colourless liquid, with a strong odour, something resembling that of the acetic. Its greatest specific gravity, according to Porrett, is 1.022. At a boiling heat, it dissolves a little sulphur, most of which, separates again on cooling. By distillation, it is partially decomposed, and some sulphur remains behind. It does not precipitate nitrate of lead, unless a little nitric acid be added, and heat applied; it is then decomposed, and sulphate of lead falls down. Hence, it contains sulphur as one of its constituents.

Five grains of sulphocyanate of copper were decomposed by nitric acid, holding hydrochlorate of barya in solution; 8.86 grains of sulphate of barya were

Abbreviations —S. sparingly soluble
S. soluble
S. S. very soluble
insol. insoluble
del. deliquesces
fus. fuses
perm. permanent
n. means that the salt is neutral
a. acid
—a. acidulous

The temperature expressed by "heat," is of course under the degree at which the salt would be decomposed.

TABLE OF VEGETABLE SUBSTANCES, NOT ACIDS.

Abbreviations.—The degrees of solubility are expressed as above. When "yellow," "green," &c. follows the sign, it expresses the colour of the solution. "Hot" or "h;" and "cold," or "c," in like manner denote the solvent to be hot or cold.

↓ denotes precipitation.

Su. N. H. A. in the column of acids, mean, respectively, sulphuric, nitric, hydrochloric, acetic. When the letter is preceded by the name of another acid, &c. it denotes that the substance is converted into it, by the action of the acid, whose initial is subjoined.

When two or more substances precede, with the numeral, 1, 2, &c. it denotes that the first named substance is first formed; by a further continuance of the action, the second, and so on. Thus gum is first converted into saclactic, then into malic, and lastly into oxalic acid, by nitric acid.

P. So. A. L. B. in the column of alkalies, denote respectively potassa, soda, ammonia, lime and barya.

a C. prefixed, that the alkali is a *carbonate*.

When no letter occurs, either in the column of acids, alkalies, oils, or galls, the effect refers generally to all the substances belonging to that column.

The action of the metallic salts, and infusion and tincture of galls, refers only to the substances in solution.

═ means no change.

Acids.	Potassa.					Barya.					Oxide of Lead.					Remarks.
	Water.	Alcohol.	Air.	Heat.	Crystals.	Water.	Alcohol.	Air.	Heat.	Crystals.	Water.	Alcohol.	Air.	Heat.	Crystals.	
Acetic	S. S.	S.	del.	fuses.	n. small plates or prisms.	S.	—S.	—efflo.	....	fine transparent needles.	S.	....	perm.	....	small needles.	Acetate of lead dissolves an equal weight of oxide of lead.
Malic	S.S.	....	del.	....	not crystallizable	—S.	insoluble.				insol.	....	....	....	....	Malate of lead precipitates in fine light flakes, soluble in acetic acid.
Oxalic	S. S.	....	—del.	....	n. flat rhombo.	insol.					—S.	insoluble.				
Benzoic	S. S.	....	del.	....	n. plumose.	S.	....	perm.			S.	S.	perm.		brilliant white.	
Citric	S.	....	del.			—S.					—S.					
Boletic	S. S.	insoluble.				—S.				—a white plates.	insol.	....	....	....	....	The precipitate from salts of lead by boletic acid, are soluble in distilled vinegar.
Gallic	S.					insol.					....	....	....	....	....	Gallic acid turns barya water purplish, and gives a flaky precipitate. It precipitates salts of yttria, glucina & zircona, but no other earthy salts
Ellagic	insol.	insoluble.	perm.	burns without fusing.	brilliant pearly scales like talc.	insol.	insoluble.	lime.								

Acids.	Potassa.					Barya.					Oxide of Lead.					Remarks.
	Water.	Alcohol.	Air.	Heat.	Crystals.	Water.	Alcohol.	Air.	Heat.	Crystals.	Water.	Alcohol.	Air.	Heat.	Crystals.	
Kinic....	S.	....	.....	....	....	S.	....	lime.	....	square plates.	S.					
Laccic...	S. S.	S.	del.	....	..	S.	....	......	....	....	....	....	....	....	....	Laccic acid gives a white precipitate with salts of iron.
Meconic.	S.	....	....	....	....	S.	....	......	....	....	....	....	....	....	....	Meconic acid, not freed entirely from colouring matter, gives a precipitate with salts of barya.
Mellitic .	S.	....	....	....	long prisms.	—S.	....	......	....	....	—S.					
Moroxylic....	....	....	....	....	....	—S.		lime.								
Sorbic ...	n. S. S.	....	....	....	not crystallizable	n. S.	......	no change	......	not crystallizable	n. —S.	....	....	....	brilliant pearly needles.	
Succinic	S. S.	....	...		n. trihedral prisms.	insol.	......	.....	......	small	insol.	....	....	....	long slender foliated.	

Acids.	Potassa.					Barya.					Oxide of Lead.					Remarks.
	Water.	Alcohol.	Air.	Heat.	Crystals.	Water.	Alcohol.	Air.	Heat.	Crystals.	Water.	Alcohol.	Air.	Heat.	Crystals.	
Tartaric.	n. S.	....	....	....	flat 4-sided rectangular prisms.	S.	....	....	....	...	insol.					
Camphoric.	—S.	S.	....	fuses.	hexagons	—S.	....	not altered.	fuses.	....	....	....	....	....	....	Camphorate of potassa, dissolved in alcohol burns with a deep blue flame.
Saclactic.	—S.	....	....	....	small	insol.	....	....	....	....	insol.					
Pyrotartaric.	S. S.	S.	del.	....	plates.	S. S.	....	....	....	....	insol.	....	....	....	....	Lead is not precipitated by pyrotartaric acid except it be first combined with a base.
Suberic.	a. S. S.	....	....	fuses.	prisms with 4 unequal sides.	—S.	....	....	....	....	insol.					
Zumic.	S. S.	S.	del.	....	not crystallized.	....	....	perm.	....	not crystallized.	....	....	perm.	....	not crystallizable	The zumates of barya and lead resemble gum in appearance.

Acids.	Potassa.					Barya.					Oxide of Lead.					Remarks.
	Water.	Alcohol.	Air.	Heat.	Crystals.	Water.	Alcohol.	Air.	Heat.	Crystals.	Water.	Alcohol.	Air.	Heat.	Crystals.	
Lampic .	S. S.	....	—del.	....	not easily crystallized.	S. S.	....	—del.	....	transparent needles.	...	....	....	....	white; easily crystallized; taste sweet.	Lampic acid poured into solutions of metallic salts, reduces the metals of several of them.
Pyromucic....	S. S.	S. S.	del.	....	not easily crystallized.	S.	insoluble.	not altered.	....	small.	Described	in	the	text.		

In the preceding tables, the salts, whose leading characters are stated in the several columns, are formed by the union of the acid named in the first column, with the respective bases which stand at the heads of the three principal divisions—Thus, acetic acid with potassa, barya, or oxide of lead, forms acetate of potassa, barya, or lead, whose properties follow on the same line with the name of the acid. e. g. acetate of potassa, is *very soluble* in *water*; *soluble* in *alcohol*; *deliquesces* in the *air*; *fuses* by *heat*; is a *neutral* salt, and *crystallizes* in *small plates* or *prisms*.

Vegetable proximate principles.	Water.	Alcohol.	Ether.	Acids.	Alkalies.	Oils fixed and essential.	Inf. Galls and Tinct. do.	Acet. Lead.	Hy. Ch. Tin.	Sulph. Iron.	Cor. Sub.	Remarks.
Sugar.....	S. S.	S.	insoluble.	Oxalic N.	becomes bitter. P.	Compound mixes with water. F.	...	....	....	....	....	Sugar is not changed by exposure to the air. When heated it first melts, and swells up.
Sarcocol ...	S. yellow.	S. yellow	....	white + N.	becomes green. P.	....	slight + inf. copious + tinc	milky.	....	+ after some hours.	....	Sarcocol first softens by heat.
Gum.....	S. S.	insoluble. + it from water.	insoluble.	1. saclactic. 2. malic. 3. oxalic N.	S. at first curdy. P.	insoluble.	....	=	=	=	=	Gum is permanent in the air; softens by heat.
Mucus....	S. S.	insoluble.	....	....	....	....	= inf.	copious +	+	=per sul.		
Jelly......	—S. cold. S. S. hot.	....		oxalic. N.	S.	....	....	....	....	....		
Ulmin	—S.	—S.	....	....	S. S. C. P.	....	= C. P.	+ brown flakes.	...	+ dark brown, from sol. in alcohol.	....	Ulmin when heated swells up, and inflames.

Vegetable proximate principles.	Water.	Alcohol.	Ether.	Acids.	Alkalies.	Oils fixed and essential.	Inf. Galls and Tinct. do.	Acet. Lead.	Hy. Ch. Tin.	Sulph. Iron.	Cor. Sub.	Remarks.
Polychroite	S. S.	S. S.	insoluble.	blue. Su. green. N. with aqueous solution.	yellow L. red. B. with aqueous solution.	insoluble.	....	=	....	↓. dark brown.	....	Polychroite deliquesces in the air.
Hematin . .	S. orange red, hot; yellow, cold.	S.	....	yellow, then red, with aqueous solution.	purplish red, with aqueous solution.	....	....	↓ blue.	↓ blue.	↓ blue.	....	
Chlorophyle . . .	—S.	S. S.	S. S.	dissolves Su. Do ....A. colour destroyed N.	S. S.	S. S.	....	....	....	....	....	Chlorophyle is permanent in the air; softens by heat.
Caffein	S.	S.	....	becomes brown by Su.	aqueous solution becomes garnet red by alkalies. ↓ brown B.	....	....	....	↓ copious, yellow.	↓. green from concentrated solution. Dilute sol. turns green without ↓.	....	Caffein is permanent in the air; is not precipitated by gelatine. The precipitates by iron and tin dissolve in all acids, and lose their colour.

Vegetable proximate principles.	Water.	Alcohol.	Ether.	Acids.	Alkalies.	Oils fixed and essential.	Inf. Galls and Tinct. do.	Acet. Lead.	Hy. Ch. Tin.	Sulph. Iron.	Cor. Sub.	Remarks.
Quassin	S. S.	S. S.	....	....	= on the dilute solution.	....	=	† copious.	† with concentrated solution.	=	=	Softens and swells when heated. Nitrate of bismuth, though precipitated by pure water, is not thrown down by solution of quassin; acetate of lead, and nitrate of silver, are the only two bodies that throw it down, from its diluted solution.
Scillitin ...	S. S.	S. S.	....	nosaclactic acid formed by N,	....	....	....	....	....	...	....	Scillitin deliquesces in the air. It swells up extremely by heat.

Vegetable proximate principles.	Water.	Alcohol.	Ether.	Acids.	Alkalies.	Oils fixed and essential.	Inf. Galls. and Tinct. do.	Acet. Lead.	Hh. Ch. Tin.	Sulph. Tin.	Cor. Sub.	Remarks.
Yellow bitter principle.	S.	S.	....	....	forms small yellow prismatic crystals P. same with A. combines with B. and L.	....	....	....	....	....	....	The crystals formed with potassa burn on hot charcoal like gunpowder, and detonate by percussion, with a purple light: they are bitter, permanent in the air, and less soluble than caffein.
Picrotoxine	—S.	—S.	....	dissolves readily, and forms neutral salts.	....	....	....	....	....	....	....	
Daphnin ..	—S. cold. S. hot.	....	....	....	....	.....	....	=	....	....	.....	When heated evaporates rapidly in sharp vapours.

Vegetable proximate principles.	Water.	Alcohol.	Ether.	Acids.	Alkalies.	Oils fixed and essential,	Inf. Galls and Tinct. do.	Acet. Lead.	Hy. Ch. Tin.	Sulph. Iron.	Cor. Sub.	Remarks,
Morphia.	—S. boiling.	S. S.	S. S.	combines readily and forms salts, which crystallize.	....	....	....	....	....	....	....	Solutions of morphia turn turmeric brown, and restore blues reddened by vinegar. It melts in a gentle heat, and has the appearance of melted sulphur. It combines with sulphur, but the compound soon decomposes, evolving sulphuretted hydrogen.
Vauqueline	—S.	S. S.	....	neutral salts, soluble in water, and crystallizable.	....	....	....	....	....	....	....	Acts on vegetable colours as an alkali. Strong nitric acid decomposes vauqueline, forms a blood red solution, which becomes yellow, and affords oxalic acid. Acetate S. S. Sulphate S. crystallizes in rhomboidal plates.

Vegetable proximate principles.	Water.	Alcohol.	Ether.	Acids.	Alkalies.	Oils fixed and essential.	Inf. Galls and Tinct. do.	Acet. Lead.	Hy. Ch. Tin.	Sulph. Iron.	Cor. Sub.	Remarks.
Nicotin....	S.	S.	....	....	....	....	↓ tinct.	....	....	....	....	Nicotin volatilizes by heat; it is poisonous, and resembles the essential oils in its properties.
Extractive.	S. reddens litmus.	S.	insoluble.	↓ Su. and H. from solution in water.	↓	....	....		↓ brown	↓	↓	↓ by chlorine, copious, dark yellow; ↓ insoluble in water; ↓ by sulphate of alumina.
Emetin....	S. S.	S.	insoluble.	red, then yellow; oxalic N. not changed. H.	S.	....	↓ infus.	↓ copious.	....	....	↓	By strong heat swells and blackens; becomes moist in damp air. ↓ red by iodine. Half a grain occasions violent vomiting; six grains ditto, and death.

Vegetable proximate principles.	Water.	Alcohol.	Ether.	Acids.	Alkalies.	Oils fixed and essential.	Inf. Galls and Tinct. do.	Acet. Lead.	Hy. Ch. Tin.	Sulph. Iron.	Cor. Sub.	Remarks.
Asparagin	S. hot. —S. cold.	insoluble.	....	S. yellow N.	S.	....	=	=	....	....	....	Swells with heat, and emits vapours, which affect the eyes like the smoke of wood.
Cerasin ...	—S. S. hot: insoluble cold.	insoluble.	insoluble.	—S. Su. —S. N. —S. H.	—S.	....	....	†	†	= per-sulphate.	....	
Inulin	S. hot: insoluble cold.	† white powder from aqueous solution.	...	1 malic. 2 oxalic N.	....	....	....	....	....	....	....	
Starch	insoluble cold: —S. hot.	insoluble.	insoluble.	S. hot dilut. Su. S. dilute N. solution green: S. strong H.	† B. S. opaline P.	....	S. inf. hot insol. cold redissolved at 120°	=	=	=	....	Melts by heat.

Vegetable proximate principles.	Water.	Alcohol.	Ether.	Acids.	Alkalies.	Oils fixed and essential.	Inf. Galls and Tinc. Do.	Acet. Lead.	Hy. Ch. Tin.	Sulph. Iron.	Cor. Sub.	Remarks.
Indigo	insoluble.	—S.	insoluble.	S.... Su. 1 Tannin 2 Oxalic 3 Benzoic 4 Bitter principle, N. insol. H.	insol. S. if fresh precipitated	insoluble.	....	....	....	....	....	By heat emits a bluish red smoke, which condenses in acicular crystals of pure indigo. Chlorine destroys its colour. Alkalies turn sulphate of indigo green.
Gluten....	—S.	insoluble.	insoluble.	S..... A. S..... H. decomposed, Su. 1. oxalic 2. malic 3. yellow, oily flakes N.	S.	....	V. inf.	....	....	....	....	Suddenly heated swells up prodigiously if moist; when dry gluten is heated it cracks, swells, and burns with the smell of horn or feathers.

Vegetable proximate principles.	Water.	Alcohol.	Ether.	Acids.	Alkalies.	Oils fixed and essential.	Inf. Galls and Tinct. do.	Acet. Lead.	Hy. Ch. Tin.	Sulph. Tin.	Cor. Sub.	Remarks.
Pollenin. ...	insoluble.	insoluble.	insoluble.	....	S. Dr. John. insol. Bucholz.	insoluble.	....	...	....	...	...	Burns readily with flame; exposed to the air it gets the smell and taste of cheese, and putrifies.
Fibrin	insoluble.	insoluble.	....	S.	insoluble.	....	....	....	....	....	......	If kept damp putrifies, and turns green; melts by heat, and drops of grease exude; a smoke volatilizing with the odour of fat.
Fixed Oils .	insoluble.	— S.	— S.	brown S. thick and white } N no change cold, black, hot H. }	soaps.	.....	....	....	....	....	......	

Vegetable proximate principles.	Water.	Alcohol.	Sulphuric Ether.	Acids.	Alkalies.	Oils fixed and essential.	Inf. Galls and Tinct. do.	Acet: Lead.	Hy. Ch. Tin.	Sulph. Iron.	Cor. Sub.	Remarks.
Wax......	insoluble.	insol. cold S. hot.	insoluble.	insoluble.	S forms a soap.	—S.						
Volatile oils	—S.	S. & S. S.	S.	blackened Su. inflame. N. & Su. 1. prussic 2. malic 3. oxalic darker, H	—S. } N.	S.S. Fixed						
Camphor...	—S.	S. S.	S.	brown Su camph. acid N. S.....H. S.....A.	insoluble.	S.						
Natural Birdlime.	insoluble.	—S.	S. S.	......	insoluble.	S.						
Artificial do. ...	Do.	Do.	Do.	black Su. S. hot N. insol. cold H. black hot H. —S. A.	—S. and forms a white magma P.	S. . E.						

Vegetable proximate principles.	Water.	Alcohol.	Sulphuric Ether.	Acids.	Alkalies.	Oils fixed and essential.	Inf. Galls and Tinct. do.	Acet. Lead.	Hy. Ch. Tin.	Sulph. Iron.	Cor. Sub.	Remarks.
Resins	insoluble.	S.	S.	S. and tannin is formedSu Do. . N. S. . . H S. . . A.	S.	S.						
Guaiacum .	—S.	S. S.	S.	S. S. . Su S. S. oxalic N. —S. . . H	S. S.		. . .	. . .	. . .	. . .	. . .	Sol. of guaiacum in Su. acid is deep red; water throws down a lilac precipitate.
Balsams ...	S.	S. S.	S. S.	S.	S.							
Gum Resins	—S.	—S.	. . .	S. and tannin formedSu Do. . N.	S.							
Caoutchouc	insoluble.	insoluble.	S.	Scarce any action.	—S.	S. . . . E.	. . .	. . .	. . .	. . .	. . .	Melts readily by heat.
Suber	—S. yellow.	—S.	. . .	yellow 1. suberic acid. 2. waxy matter. 3. tannin 4. starchy matter N.								

Vegetable proximate principles.	Water.	Alcohol.	Ether.	Acids.	Alkalies.	Oils fixed and essential.	Inf. Galls and Tinct. do.	Acet. Lead.	Hy. Ch. Tin.	Sulph. Iron.	Cor. Sub.	Remarks.
Medullin..	insoluble.	insoluble.	insoluble.	S. oxalic. N.	. . .	insoluble.						
Wood	insoluble	insoluble	. . .	1. oxalic. 2. citric. 3. malic. 4. acetic. N.	S. in weak solution P Do...So:							
Fungin....	insoluble.	insoluble.	insoluble.	—S. gelatinous H. 1. prussic 2. oxalic. N.	scarce any action with weak sol. P. Do....So: —S. strong P. —S.... A.	insoluble.	absorbs the tannin and becomes fawn coloured.					

Animal proximate principles.	Water.	Alcohol.	Ether.	Acids.	Alkalies.	Oils fixed and essential.	Inf. Galls and Tinct. do.	Acet. Lead.	Hy Ch. Tin.	Sulph. Iron.	Cor. Sub.	Remarks.
Gelatine ..	—S. when solid. S.S. in its soft state, and the water hot	insoluble.	insoluble.	S.S. N&H S.....Su.	S. S.	Forms an emulsion.	↓ copious. White.	=	=	—↓ yellow flakes.	↓ copious.	
Albumen in its natural uncoagulated state.	S. S.	coagulates.	coagulates.	coagulates. redis. Su. Do. N. Do. H.	=dilute. Gelatinizes when triturated with saturated solution P.	....	↓ copious. Yellow.	↓ copious.	—↓	↓ brown flakes.	↓	
Fibrin ...	insol. cold —S. hot.	S. decomposed forms a substance like adipocire.	S. similar to alcohol.	S.....A. —S...H. insol. N.	S. yellow inclining to green.	....	↓ white flocks.	....	....	....	....	↓ by alkalies from sol. in acetic acid; also by pruss. potassa, & all the strong acids.
Colouring matter of blood.	insol. cold --S. hot.	S. similar to its action on Fibrin:	S. similar to alcohol.	S. S.	S. purple.	....	↓ from sol. in N. acid.	↓ from sol. in N. acid.	....	....	↓ red from sol. in N. acid.	
Mucus	S.	insoluble.	insoluble.	S. S.	....	....	=	↓ copious by sub. acet. lead.	....	....	=	Nitrate of silver ↓ mucus.

Animal proximate principles.	Water.	Alcohol.	Ether.	Acids.	Alkalies.	Oils fixed and essential.	Inf. Galls and Tinct. do.	Acet. Lead.	Hy. Ch. Tin.	Sulph. Iron.	Cor. Sub.	Remarks.
Osmazome.	S.	S.	....	....	....	....	↓	↓	....	....	....	
Picromel ..	S. S.	S. S.	insoluble. converted into an adipocirous substance.	S. if the acid be not in excess.	....	....	—	↓ sub-acetate.	..	↓	↓ by *nitrate of mercury.*	Combines with many oxides, and forms a pulverulent mass.
Urea......	S. S.	S.S. yields crystals very readily by evaporation.	....	↓ pearly crystals N S....H	S.	....	No. ↓ yellow brown.	....	...	....	....	Crystallized urea is decomposed by nitric acid with violent action, into a red liquid, and a white concrete matter which detonates like nitrate of ammonia.
Sugar of Milk.	S. S.	insoluble.	insoluble.	saclactic. N. S....H. Do...A.	S.S. deep brown P.	....	....	....	....	....	....	The addition of a little sulp. acid renders it soluble in alcohol.

Animal proximate principles.	Water.	Alcohol.	Ether.	Acids.	Alkalies.	Oils fixed and essential.	Inf. Galls and Tinct.do.	Acet. Lead.	Hy. Ch. Tin.	Sulph. Iron.	Cor. Sub.	Remarks.
Cantharadin	insoluble.	insol. cold S. boiling. crystallizes on cooling.	—S.	....	....	S. S.	....	....	....	......	....	
Cochenelin.	S. S. fine red: a very small quantity produces the effect.	S. the more so as the alcohol is weaker.	insoluble.	= colour changes to yellow by dilute acids.	colour becomes violet crimson.	insoluble.	=	+ copious violet.	+ copious, violet, prot. oxide. No. + deutoxide.	No. + brown tinge.	=	The aqueous solution becomes syrupy by evaporation, but affords no crystals. Chlorine turns it yellow, and destroys the colour.
Fat	insoluble.	insoluble.	insoluble.	yellow ointment and saclactic N.	forms soap.	.. ..	....	....	....	....	....	
Stearin ...	insoluble.	S. hot; most S. in the strongest alcohol.	....	....	forms soap.	....	....	....	....	......	....	
Elain......	insoluble.	S.	....	....	forms soap.	....	....	....	......	......	......	

Animal proximate principles.	Water.	Alcohol.	Ether.	Acids.	Alkalies.	Oils fixed and essential.	Inf. Galls and Tinct. do.	Acet. Lead.	Hy. Ch. Tin.	Sulph. Iron.	Cor. Sub.	Remarks.
Ambergris.	insoluble.	S. in part cold; the remainder S. hot.	....	—S. . N. liquid brown leaves a resin by evaporation.	S. forms soap.	S.	....	....	....	....	....	
Uric acid...	—S.	insoluble	....	S. pink N.	—S.	....	....	†	†	† reddish.	†	The action on the metallic salts is supposed to be that of the urate of potassa; uncombined uric acid is incapable of decomposing them.
Rosacic acid	S. S. hot.	......	....	1. deep red.—2 uric acid. Su. & N.	......	....	....	....	Hy. Ch. Gold. † violet.	....	....	The existence of this substance, as a peculiar acid, is questionable.
Purpuric acid	—S. hot, requiring more than 10000 pts of water.	insoluble.	insoluble.	S. S. concentrated & in excess.	S. S.	....	rose red, No. †	....	† white pearly crystals by standing.	yellowish red No. †	† light rose colour by standing.	The metallic precipitates are by purpurate of ammonia.

Animal proximate principles.	Water.	Alcohol.	Ether.	Acids.	Alkalies.	Oils fixed and essential.	Inf. Galls and Tinct. do.	Acet. Lead.	Hy. Ch. Tin.	Sulph. Iron.	Cor. Sub.	Remarks.
Amniotic acid.	—S. cold. S. hot.	S. hot.	....	....	S.	....	....	=	....	....	=	
Margaric acid.	insoluble.	S. S.	....	....	forms insoluble soaps.	....	....	+				
Oleic Acid.	insoluble.	S. S.	....	....	forms soluble soaps.							
Lactic acid.	S. S.	S. S.	....	....	S.	....	....	....	....	....	....	Lactate of potassa, does not give any smell of acetic acid, by the action of sulphuric acid.

On the ultimate Analysis of Vegetable and Animal Substances.

§ 293. - The mode of ascertaining the nature and proportions of the ultimate elements of organized substances was, till within a few years, confined to what was called destructive distillation; that is, to the action of heat applied to those bodies in close vessels, connected with proper receivers; by which all their volatile ingredients were driven off and collected, and nothing but charcoal remained in the retort, and from these products the proportions of the elements in the original compound were estimated. Thus, Fourcroy and Vauquelin obtained by distilling 100 parts of urea, 92 carbt. ammonia, 4.65 hydruret of carbon, and 3.35 of charcoal; from whence it was calculated that urea is composed of

39.5	oxygen.
32.5	azote.
14.7	carbon.
13.3	hydrogen.
100.0	

Lavoisier endeavoured to accomplish the analysis of organized bodies by burning them in oxygen gas, and M. M. Gay Lussac and Thenard have lately proposed a different method of examining vegetable and animal substances, which consists in changing them into water, carbonic acid, and azote by combustion by means of chlorate of potassa in a peculiar apparatus. This apparatus (pl. 2, fig. 14.) is formed of three separate pieces. One of them *a. a.* is a very thick glass tube, closed at the lower and open at the upper extremity, about 7½ inches long, and $\frac{3}{10}$ths of an inch wide; a very small glass tube *b. b.* is united to it laterally at about 2 inches below its opening. The next piece is a brass cap *c. c.* into which the open end of the large brass tube is inserted and fixed with a cement that does not melt at a temperature below 104°. The last piece is a stop-cock of peculiar construction, *d. d.* which constitutes the whole merit of the apparatus. The key of this stop-cock turns in every direction without admitting any air to pass, and instead of being perforated, has merely a small cavity sunk in its surface near the middle, and capable of holding a portion of matter about the size of a small pea. When the key is in its upper position, the cavity corresponds to a small funnel, *e.* that enters the socket or body of the stop-cock, and when brought to its lower position it communicates with and forms a continuation of the stem of the stop-cock, which is hollow and screws into the cap *c. c.* When any substance is placed in the funnel it falls into the cavity in the key, which being then turned round, conveys it into the stem of the stop-cock, from whence it falls into the cap, and so to the bottom of the glass tube. Pl, 2, fig. 15, is the stop-cock fitted to the cap only; the stem of the stop-cock, figs. 14 and 15, passes through a small basin *f. f.* the use of which will be stated hereafter.

§ 294. About ten or twenty grains of the subject of the analysis must first be well mixed by trituration, with a due proportion of chlorate of potassa, which is easily ascertained by projecting portions of the mixture into a glass tube, whose extremity is heated nearly red. If the residuum, after the combustion, be not perfectly white, more chlorate must be added, and the salt should always be in such excess as to ensure the perfect combustion of the vegetable or animal matter. The purity of the chlorate must also be ascertained with great accuracy; for this purpose put 100 grains of the salt, perfectly dried at 212°, into a very dry, and previously weighed small glass retort, taking care that none adhere to its neck; adapt a tube to the retort, so bent as to pass into a receiver, full of and inverted over water, and reach to its top. Heat the retort gradually to redness, and continue the heat till the chlorate ceases to give off any more oxygen; then let the apparatus get quite cool before it is taken to pieces; thus, as much air will return into the retort as was expelled by the heat, and consequently the quantity of elastic fluid in the jar will correctly represent that of the oxygen given off by the chlorate. The purity of the gas may then be examined by the usual tests, remembering to allow for the proportion of atmospheric air contained in the apparatus prior to the experiment, which is easily done by ascertaining the capacity of the retort and its tube. M. Thenard directs the chlorate to be previously fused in a hessian crucible, and then to be finely pulverised in a clean brass mortar.

The ingredients being well incorporated by trituration, and carefully dried at 212° and weighed, are to be made into a paste with distilled water, and formed into small pellets, of such a size as to fall readily into the cavity in the key of the stop-cock, and then thoroughly dried again at the same temperature. If the subject of the experiment be an acid, it must be first combined with a base, either lime or barya, and the dry salt analysed instead of the pure acid; in this case the carbonic acid formed in the process will unite to the base, and its quantity must be ascertained in the usual manner. If the vegetable or animal matter contain any substance foreign to its nature, its quantity must be ascertained by projecting a weighed portion by degrees into a red hot platina crucible, whose tare has been previously taken; the vegetable or animal substance will be charred and burnt away, and the impurities left in the crucible.

§ 295. Let the key of the stop-cock be greased with a very little of a mixture of oil and tallow, that it may not leak, and fix the apparatus in the manner following:

A. Make a hole through a brick *t*, and sink the glass tube *a. a.* into it, as far as the small lateral tube *b. b.* then place the two ends of the brick on two little parallel walls built up on a table near the mercurial trough, the same height with it, and within half an inch of one another, and rest the lower end of the tube *a. a.* on the iron grate *g*, which is supported by being inserted in the walls.

B. Immerse the little lateral tube *b. b.* in the mercurial bath, and fix a slate between the brick and the tube, that it may not be heated; the tube *a. a.* being first firmly fixed in the brick with fire lute.

C. Pieces of burning charcoal must be put by degrees on the grate and round the lower end of the tube *a. a.* and at the same time some ice in the little brass basin *f. f.* that the grease may not melt nor the stop-cock leak; a spirit of wine lamp *h. h.* must then be placed under the grate *g.* and immediately below the tube *a. a.* the lower part of which will soon be nearly dull red hot, when the end of the bent tube *b. b.* must be introduced under a small receiver full of mercury, and a certain number of the little balls, which it is unnecessary to weigh, dropped, by means of the stop-cock, into the tube *a. a.* Each pellet takes fire almost as soon as it falls, and occasions an immediate and pretty considerable disengagement of gas; by these means all the air of the apparatus is driven out, and replaced by precisely the same gas as must remain at the end of the experiment.

D. When about twenty of the pellets have been thus decomposed in the tube *a. a.* incline the brick so as to immerse the bent tube deeper in the mercury. Take away the jar which has received the gases, and put a graduated one full of mercury in its place.

E. The apparatus being thus arranged, drop a certain number of the little balls one after another into the tube *a. a.* till the bottle is full of gas, when it must be removed, and another introduced into its place, and the operation continued till a sufficient quantity of the subject of the analysis has been decomposed.

F. The tube, during the whole process, should be kept at the greatest heat it can bear without fusing, to obviate as much as possible the formation of any hydruretted carbon, or carbonic oxide. To ascertain if either of those gases be notwithstanding produced, detonate two hundred parts of the gas obtained, with 40 parts of hydrogen in the mercurial eudiometer, by the electric spark. The hydrogen will be burnt by the excess of oxygen in the gas obtained in the experiment, as well as the other inflammable gases, if any be present, which will be known by measuring the residuum after the detonation, for if the gas contained neither, the absorption will be equal to one volume and a half of the hydrogen employed, but otherwise greater, and so much the more as they prevail in the mixture. It is evident that the quantity of chlorate used to decompose the vegetable matter, must be such as to afford a considerable excess of oxygen. Should the absorption after detonation not amount to one volume and a half of the hydrogen employed, there is a deficiency of oxygen; an additional known quantity must therefore be added, and the electrical spark again passed through the mixture.

It is unnecessary to dwell on the analysis of the gases; sufficient directions have already been given on that subject in the beginning of this work.

I subjoin a table containing the results of the analyses of fifteen vegetable substances, examined by M. M. Gay Lussac and Thenard.

TABLE

OF THE PROPORTIONS OF THE ELEMENTS OF FIFTEEN VEGETABLE SUBSTANCES.

				Supposing the oxygen and hydrogen to exist as water.		
Substances analysed.	Carbon.	Oxygen.	Hydrogen.	Carbon.	Water.	Oxygen in excess.
Sugar	42.47	50.63	6.90	42.47	57.53	0
Gum Arabic	42.23	50.84	6.93	42.23	57.77	0
Starch. . . .	43.55	49.68	6.77	43.55	56.45	0
Sugar of Milk	38.825	53,834	7.341	38.825	61.175	0
Oak	52.53	41.78	5.69	52.53	47.47	0
Beech	51.45	42.73	5.82	51.45	48.55	0
Mucus Acid .	33.69	62.67	3.62	33.69	30.16	36.15
Oxalic	26.57	70.69	2.74	26.57	22.87	50.56
Tartaric . .	24.05	69.32	6.63	24.05	55.24	20.71
Citric	33.81	59.86	6.33	33.81	52.75	13.44
Acetic . . .	50.23	44.15	5.63	50.22	46.91	2.87
						Hydrogen in excess.
Turpentine	75.94	13.34	10.72	75.94	15.16	8.90
Copal	76.81	10.61	12.58	76.81	12.05	11.14
Wax	81.79	5.54	12.67	81.79	6.30	11.91
Olive Oil . .	77.21	9.43	13.36	77.21	10.71	12.08

§ 296. In the analysis of animal substances, which in all respects is conducted precisely like that of vegetables, it is essential that the chlorate of potassa be not in excess, for in that case a portion of nitrous gas is always formed, in greater quantity as the temperature is less elevated, and the subject of the analysis abounds in azote. It is easy to ascertain the necessary proportions of chlorate and animal matter, by projecting a mixture of known composition, into a red hot crucible, and diminishing or increasing the dose of chlorate, till the residual matter has a light grey colour: as in the decomposition of vegetable substances, the bottom of the glass tube, must be kept at the greatest heat it can bear without fusing, during the whole operation. To be certain that neither nitrous gas, nor ammonia are produced, expose slips of moistened litmus and turmeric papers to the fumes arising from the decomposing animal matter.

The following are the results of M. M. Gay Lussac and Thenard's analyses of the four most common animal substances, fibrin, albumen, gelatin, and caseous matter.

Substances analysed.	Carbon.	Oxygen.	Hydrogen.	Azote.
Fibrin	53.360	19.865	7.021	19.984
Albumen	52.883	23.872	7.540	15.705
Caseous matter . .	59.781	11.409	7.429	21.381
Gelatin	47.881	27.207	7.914	16.988

I feel much indebted to the kindness of my friend Mr. I. F. Daniell, for the following observations, drawn up at my request, on the preceding apparatus and mode of analysis. He is the only person, as far as I know, who has made a trial of it in this country.

I give the observations in Mr. Daniell's own words:—

"Dear Sir,

"According to your request, I send you a few observations upon M. M. Gay Lussac and Thenard's apparatus for the analysis of vegetable bodies. The objections which have been hitherto advanced against it, have been chiefly theoretical; my remarks shall be wholly practical, and if you think that they may tend in any way to point out sources of error, or to remove difficulties of operation, it will give me great pleasure that you should make use of them in any way that may best answer your purpose.

"In selecting glass tubes for the operation, it is highly necessary to have them very carefully annealed, as otherwise, whatever care be taken in the application of the heat, they are almost sure to crack. The operation of welding in the lateral glass tube is very difficult and uncertain; I have therefore made use of a brass tube, proceeding from the socket by which the cock is attached to the glass tube. The socket and the tube are made to fit one another by grinding. I have also found it essential to have a case of thin iron made to surround the part which is exposed to the fire, for without this precaution, although the heat never exceeded a dull red, the bottom of the tube was invariably blown out into a bulb, and finally burst. As this difficulty is not pointed out in M. Thenard's book, I take it for granted that it arises from the greater fusibility of the English than the French glass. The space between the tube and its case, which was as small as possible, I filled with a mixture of clay and sand. In this manner I succeeded perfectly in decomposing the balls.

" I have two objections to make to the results, which, although they may appear trifling separately, yet their amount combined, seems to be sufficient to affect an operation in which such very minute portions of the substance to be analysed, are employed, and especially when it is recollected that loss of weight is one of the essential elements of the calculation.

" In the first place a considerable portion of the chlorate of potash sublimes, and condensing in the colder part of the tube escapes decomposition.

" In the second place, the air in the apparatus being kept in a state of greater or less condensation by the pressure of the mercury, every time the cock is turned, after having dropped the ball, a portion condensed in the cavity escapes with a whizzing sound. This is very audible when the lateral tube is plunged less than an inch in the mercury.

" It is obvious that both these objections may be very much decreased by care and attention, but I do not think it possible entirely to remove them. They are at any rate possible sources of error, which it may not be useless to point out.

" In conclusion, I will just direct your attention to an inadvertence of M. Thenard in the directions which he has given for conducting this process, which is at least important in the analysis of vegetable and animal acids. He says that a certain number of little balls which *it is useless to weigh*, are let fall successively into the tube as a preliminary operation for expelling the common air of the apparatus. Now *it is necessary* to weigh them in order to calculate precisely the quantity of carbonic acid combined with the barytes, when the operation is finished.

"Sincerely your's,

"I. F. Daniell."

16*th February*, 1819.

The fourth volume of the Annals of Philosophy contains a paper by Berzelius, "On the definite proportions in which the elements of organic nature are combined," in which a modification of the preceding process is described. He also used chlorate of potassa, first combining the substance to be examined with oxide of lead, and added a tube containing chloride of calcium, to collect the water formed in the experiment. This method, Dr. Thomson observes, is obviously better than that of the French chemists, who could not, by their apparatus, estimate the quantity of the water, but, neither by their method nor by that of Berzelius can the composition of these bodies which contain azote, be accurately determined.

The following method, by means of peroxide of copper, which has been practised by Berard and other chemists, but was first used by Gay Lussac in the analysis of uric acid, seems in Dr. Thomson's estimation preferable to either of the foregoing; he says he has often practised it; I cannot therefore do better, than give the reader the account of it in his own words, as I find them in the third volume of the Supplement to the Encyclopedia Britannica, p. 527.

"Procure a copper tube, bored from a solid copper rod about twelve inches long, and with a bore of about one-third of an inch in diameter. To the mouth of this tube a brass tube must be ground air-tight. This brass tube may be about four inches long, and bent near the middle at an angle of about 45°. To the opposite end of the brass tube, a glass tube about six inches long is fitted, so as to be nearly air-tight. This glass tube is bent at the end, so that it can be introduced below the mouth of a glass jar, standing inverted upon the mercurial trough and full of mercury. The glass tube is filled with dry muriate of lime, in the state of powder. The upper and lower ends are filled with amianthus. Its weight must be carefully ascertained and written down. For greater security, let the glass tube be luted to the brass tube. Fill the brass tube with amianthus. Weigh out three grains of the vegetable substance to be analysed. It is best to take it in its natural state, without freeing it from the water which it may contain. This water must be ascertained by other experiments, and its quantity allowed for in the analysis. Mix these three grains with 120 grains of peroxide of copper, previously reduced to the state of a fine powder. The mixture must be as intimate as possible, that is to say, the vegetable substance must be equally diffused through the whole of the oxide of copper. Put the mixture into the copper tube; it will fill about five inches of it; fill up the tube now completely to the mouth with peroxide of copper, and put a little amianthus over it, to prevent any of the oxide from falling out. Then fix the brass tube in the copper one. Put the copper tube upon a small iron chaffer or cradle, so that one half of the tube is within the chaffer, and the other half on the outside, and the whole apparatus must be so placed, that the extremity of the glass tube is below an inverted glass jar, standing over mercury in the mercurial trough. That portion of the copper tube, which is on the outside of the chaffer, is now to be covered with a coat of moist clay, about an inch in thickness. This covering will prevent the heat from passing nearly so rapidly along the copper tube; the consequence of which will be, that the brass tube will remain comparatively cool during the whole experiment. A few pieces of burning charcoal are now placed round the portion of the copper tube which is within the chaffer. The fire is made to commence at the end of the tube nearest the mercurial trough, and it proceeds gradually backwards to the bottom of the tube. Care should be taken to keep the fire low, and to let the combustion proceed slowly. The copper tube need hardly be heated red hot: though, to be sure that the combustion has been complete, we are always in the habit, just before we terminate the process, to make the whole of the copper tube within the chaffer distinctly red hot. If the vegetable substance analysed happens to contain azote, there seems to be a temperature somewhere about a red heat, at which nitric acid is formed. As such a product would destroy the accuracy of the experiment, it is material to keep the heat so low as to prevent the risk of any such formation.

" As soon as the temperature rises sufficiently high, the vegetable substance is completely decomposed. The carbon which was contained in it, combines with oxygen, contained in the oxide of copper, and is converted into carbonic acid. The hydrogen combines with oxygen, and is converted into water, while the azote makes its escape in the gaseous state. The carbonic acid and azotic gases will be collected in the graduated glass jar over the mercury. To ascertain the bulk of each, let up into the jar a quantity of potash ley, and let it stand in contact with the gases for twenty-four hours. The whole of the carbonic acid will be absorbed. The diminution of bulk will give the quantity of carbonic acid, while the residual bulk will give the quantity of azotic gas; making allowance for the alteration in the bulk occasioned by the column of mercury in the jar, and by any change of temperature that may have taken place during the continuance of the experiment. Indeed it is always necessary to reduce the gases to the bulk which they would occupy at the standard temperature of 60°, and when the height of the barometer is 30 inches. Knowing the bulk of these gases, it is easy to deduce their weight, and hence to know the quantity of carbon and azote which the three grains of the vegetable substance analysed contained. The increased weight of the muriate of lime will give us the water formed by the process, or separated from the vegetable substance by the heat. Subtracting from this weight the known proportion of water contained in the vegetable substance, determined by other experiments, the remainder will be the water formed by the union of the hydrogen in the vegetable substance with the oxygen of the oxide; $\frac{10}{85}$ of the weight of this water is the hydrogen contained in the three grains of vegetable substance analysed. Thus we determine the weight of the azote, carbon, and hydrogen, which our vegetable substance contains. Add all these weights together. If they amount to three grains, we may conclude that our substance contains no oxygen; but if the weight, (as will almost always happen) be less than three grains, we must suppose that the substance contained a quantity of oxygen, the weight of which, when added to that of the other constituents, will make up the weight of three grains, the water which exists as a constituent of the body being supposed subtracted."

Dr. Prout, by this method of analysis, found uric acid, to be composed of

hydrogen	2.857
carbon	34.286
azote	40.000
oxygen . . .	22.857
	100.000

The probable atomic composition of an animal or vegetable substance cannot well be arrived at, by merely knowing the quantities of the ultimate elements of which it is composed. It is also necessary to ascertain the combinations it is capable of forming with substances of known composition. We have seen (§ 102) that when an acid combines with a metallic oxide, the oxygen in the former bears a certain proportion to that in the latter, and in the mineral acids, it generally amounts to two or three atoms in the acid for one in the base. By applying this rule to vegetable and animal substances, we obtain a ready method of finding the number of atoms of oxygen which they contain, at least those that are capable of forming chemical compounds with known oxides, and hence it is easy to determine the number of atoms of the other elements.

An example will render this clearer. Berzelius found gallate of lead composed of

gallic acid . . .	100
oxide of lead . .	174

174 of oxide of lead contain 12.44 of oxygen, and, supposing the salt to consist of an atom of acid and one of the base, the equivalent number of the former is 60, that of oxide of lead being 104.5 The analysis of gallic acid, by combustion with chlorate of potassa, gave the same chemist

hydrogen	5.
carbon	56.64
oxygen	38.36
	100.00

Since the oxygen in the acid is proportionate to that in the base, if we divide the quantity obtained from 100 parts of the former by that contained in the portion of oxide required for their saturation, the quotient will express the number of atoms of oxygen in the acid, and it will be in the same ratio to the number of atoms of each of the other elements of the acid as the quantity of oxygen is to their quantities respectively.

Thus $\frac{38.36}{12.44} = 3,09$, whence, omitting fractions, we may consider the number of atoms of oxygen to be 3 or $7.5 \times 3 = 22.5$ (*a*).

Again, 38.36 : 56.64 : : 22.5 : 33.22 and $\frac{33.22}{5.7} = 5.83 =$ atoms of carbon and 38.36 : 5 : : 22.5 : 3.19 = atoms of hydrogen.

(*a*) The equivalent numbers of the elements of the acid are
hydrogen 1
carbon 5.7
oxygen 7.5. (See Table of chemical equivalents. Appendix.)

The atomic composition of gallic acid may therefore be expressed thus:

oxygen	7.5 × 3	=	22.5	. . 38.36
carbon	5.7 × 6	=	34.2	. . 56.64
hydrogen	1. × 3	=	3.0	. . 5.00
			59.7	100.00

These numbers are not perfectly correct, the oxygen and hydrogen a little exceed the exact quantity, and the carbon falls something short of it; but their sum comes so near to the weight of an atom of the acid, as to justify our considering it to be constituted as above, especially when the difficulty of obtaining perfectly accurate results, in experiments of this nature, is taken into the account. The object of introducing the analysis at all in this place, is merely to shew the manner in which the atomic constitution of these bodies may be calculated. After all we must not regard it, in the present state of our knowledge, as more than an ingenious hypothesis, supported however, by strong analogies, and the utter improbability, with the satisfactory proofs we possess of the definite nature of inorganic compounds, that the more delicate structure of organised matter should want the same constancy of arrangement that prevails in the former; for whatever may be the fate of the atomic theory, whether it shall hereafter be established or overthrown, the theory of definite chemical proportions must stand immovable, for its basis is truth.

The reader who wishes to pursue this subject further, may study the elaborate essay of Professor Berzelius in the fourth and subsequent volumes of the Annals of Philosophy, with advantage.

CONCLUSION.

Before the Student can derive assistance from the preceding pages, it will be necessary for him to know to which of the six chapters, into which, as into so many classes, the subject has been divided, any substance presented for analysis, is to be referred. A few short directions will suffice for this purpose.

In general the physical properties of the substance will indicate its class. Thus no question can arise as to the gases; they clearly cannot be confounded with any other bodies, nor referred to any chapter but the second.

Mineral waters speak as plainly for themselves, their obvious characters at once shew them to belong to the sixth chapter.

Vegetable and animal substances, which occupy the seventh, are very easily distinguished, by heating a small portion in a glass tube, or on a slip of platina foil in the flame of a candle; the greatest part will burn away, leaving a black coal, and if it be animal matter, will exhale a peculiarly offensive smell, like that of burning feathers. The portion heated in the tube, will give off a large quantity of gas, with the other products of the decomposition of vegetable and animal matter, and a light, black bulky coal, will be left in the retort.

The physical properties of colour, form, and taste, will generally be sufficient to shew if a substance belong to the fifth chapter, which treats of the salts; otherwise, we must ascertain its chemical characters. If soluble in water, dissolve it, and add a caustic alkali, or alkaline sub-carbonate; if insoluble, boil it with a solution of one of those substances; an oxide or carbonate will be deposited, according to the reagent employed, (unless the base of the salt be alkaline,) whose particular nature, as well as that of the acid, which, during the decomposition of the salt will have united to the alkali, must be ascertained by the rules described in the fourth and fifth chapters.

If the substance be soluble, and no precipitate ensue on adding an alkali or its sub-carbonate, the base must be alkaline, and a reference to § 167 will show how it may be distinguished. Should the base of the salt be morphia, or picrotoxine, it will be destructible by heat, as will the acid also, if it be either animal or vegetable.

If both acid and base be combustible, they must both be derived from organized matter, and may be distinguished by the characters detailed in the seventh chapter.

The acids redden vegetable blues, and neutralize salifiable bases. Metallic oxides, with the exception of protoxide of mercury and oxide of silver, form more or less soluble and neutral salts with liquid hydrochloric acid; those which are highly oxygenated, as the peroxide of manganese, at the same time occasion the evolution of chlorine; others, as potassium, of hydrogen.

As to their physical properties, metallic oxides are solid and brittle; when in powder they have no lustre; are all, except oxide of osmium, inodorous; and only those of the metals of the second section and of osmium have any flavour; they are white or coloured, (see the table of their colours, appendix F.) heavier than water, but of less specific gravity than the metals from which they are derived, unless the metal be very light and have great attraction for oxygen, as potassium and sodium. They have no action on vegetable blues, but most of them restore their blue colour after being reddened by an acid. *(a)* The oxides of the second section, and magnesia, change the yellow colour of turmeric to brown.

As there are only two non-metallic oxides not gaseous, water and oxide of phosphorus, whose characters are strongly marked, their class cannot be mistaken. They, as well as the acids and other oxides, all belong to the fourth chapter.

If the substance belong to neither of the five chapters already enumerated, it is pretty clear it must be referred to the third, the only one remaining, and consequently is either a simple metal, an alloy, or a non-metallic combustible. For the characters of the non-metallic combustibles, consult § 38. The metals and their alloys are readily distinguished by their brilliancy, high specific gravity, (the bases of the alka-

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(*a*) Litmus appears to be a compound of a red vegetable colour with an alkali, or metallic oxide. When an acid is added to its solution, the acid combines with the base and disengages the red colour; on adding more oxide to the liquid, a new compound is formed with the reddening principle, and the blue colour reproduced. (Thenard, vol. ii. p. 3.)

lies excepted,) ductility, tenacity, and by being perfect conductors of electricity. The assemblage of all these properties, or the greater number of them, denote a substance to belong to the third chapter, and a reference to the characters detailed in the second division of it, § 39, will distinguish its individual nature (*a*).

It is hardly necessary to add that compound substances, formed of several ingredients belonging to different classes, require a more laborious examination to distinguish their elements, and cannot be referred to any particular chapter.

I have concluded my task; and though I hope it will not be found uninteresting or useless, I am conscious how very far it is from that perfection to which I would anxiously desire to raise it. Far greater leisure than I possess would be requisite to produce such a work; even a life devoted to the labour would hardly suffice, though not a short one. Every experiment, in every part of the subject, should be carefully repeated, the result of every process laid down, critically examined, and its accuracy established by comparison with other processes, tending to the same results, but differently conducted; but he who knows the time required to make one satisfactory analysis, will know the impossibility of the attempt.

Such as it is then, must this little volume go forth

(*a*) I may take this opportunity of mentioning the absolute necessity that all the re-agents and tests employed in analytical chemistry be of the utmost purity. I recommend the young chemist to adopt the useful practice of preparing them for himself, if his leisure will permit; otherwise, he may obtain them of Mr. Garden, in Oxford-street, to whose care and skill in their preparation I can bear ample testimony.

into the world—all its imperfections on its head—would they were less and fewer, not only for his sake who put it together, but for his also for whose use it is intended, the inexperienced and the learner. To higher aims it has no pretensions. To him it may serve as a humble pioneer to clear away some of the obstacles that encumber this path of chemical science; but compleat victory over the host of difficulties that will present themselves, can only be obtained by his own diligence, patience, and reflection.

APPENDIX.

A. I have a balance, whose beam (a double cone, 15 inches long, and 2⅝ inches diameter in the middle) pans, the wires which support them, and the weights, are of platina, and the knife edge, and planes they turn on of agate. This balance is sensible to the $\frac{1}{100}$dth part of a grain when loaded with 1000 grains in each pan. Platina and agate, not being liable to be acted on by corrosive vapours, render this balance peculiarly convenient for the laboratory; and the effect which changes of temperature have on this metal is so slight, as seldom to require any alteration in the adjustment. The balance was made by Fiddler.

The essential requisites in a good balance are, 1st, the points of suspension of the scales, and the centre of motion of the beam must be in a straight line; 2nd, the arms must be of equal length; 3d, the centre of gravity must be in the centre of motion; 4th the arms must be in equilibrio when the balance is empty; 5th, there must be as little friction as possible at the centre of motion. A defect in any of these properties makes the balance either imperfect or false. But it often happens that one side of the beam is made shorter than the other, and the defect covered by making that scale the heavier; by which means the scales hang in equilibrio when empty, but when they are charged with any weights, so as to be still in equilibrio, those weights are not equal, but the deceit will be shewn by changing the weights to the contrary sides, for then the equilibrium will be immediately destroyed. (Hutton's Mathematics, p. 181. vol. 2.)

B. The best method with filters is to use double papers, which (being equally dry) are first accurately balanced against one another, then folded up together, and the liquid filtered through both. When the precipitate is sufficiently washed, it is to be dried on the filter, which must not be separated from its fellow till that operation is finished. The substance and its filter are then to be placed in one pan, and the counterpoise in the other, and weighed. In most instructions for mineral analysis 100 grains of the substance at least are directed to be employed; but as correct results may frequently be obtained, by working on half or even a fourth part of that quantity.

In this microscopic chemistry, first successfully practised I believe by Dr. Wollaston, labour and expense are abridged and all the phenomena attending the experiments brought more within our observation. For apparatus, a small oil lamp and a spirit one, a few test tubes and watch glasses, some silver and platina foil, sticks of charcoal, and the blowpipe; with a sufficient assortment of pure tests, and a small delicate balance *(a)* are nearly all that is required; the parlour fire-side becomes a convenient laboratory, and the black dust and swelter of the furnace are exchanged with advantage for clean hands and comfort.

(a) Such balances have lately been made by Corless, No. 19, Newcastle-street, Strand. They are extremely sensible and accurate, and not of high price.

In this mode of operating it is better to avoid the use of filters as much as possible, and instead, to draw off the supernatant fluid from the precipitates, if they subside readily and entirely, by means of a glass tube, terminating at one extremity in a fine point, and having a bulb to collect the fluid, at about 1½ inch above it.—(See apparatus.)

If filters be unavoidable, they should be washed with distilled water before they are used. For drying filters I have found an apparatus, consisting of one cylindrical copper vessel inclosed in another, so as to leave a vacant space of about three-eighths of an inch between their sides and bottoms, extremely convenient. The filters are placed in the inner vessel; through a hole in the lid a thermometer passes, supported by a cork, and an argand lamp is placed below. With this apparatus it is easy to expose a substance to any heat between 100° and 220°, and by a little attention to regulate the lamp, a very steady temperature may be obtained. By this mode of drying we readily ascertain when all the moisture is expelled, for as long as any steam is given off the thermometer never rises above 198° or 200°.

A still simpler and more expeditious method is to place the filters in a wedgewood basin on the sand bath, with a fold of paper under them to prevent their being scorched; great accuracy is obtained in this mode, if carefully practised.

I have mentioned the blowpipe as part of the apparatus of the minute chemist; it is no less serviceable to the operator, who works on more ponderous masses, by the indications it affords of the general nature of substances, fragments of which are submitted to its agency. I shall subjoin some useful hints concerning it, taken chiefly from Gahn's Treatise, which appeared in the Annals of Philosophy for January, 1818, and from Bergman's twenty-fifth Dissertation.

Of the figure of an instrument so well known, it is needless to say any thing, but a few words on the mode of using it may not be misplaced. A continued stream of air is absolutely essential, to produce which, without fatigue to the lungs, an equable and uninterrupted inspiration must be maintained by inhaling air through the nostrils, whilst that in the mouth is forced through the tube by the compression of the cheeks. A little practice will make this operation easy, but at first considerable lassitude is generally experienced in the buccinator muscles. After habit has rendered the operation familiar, a current may be kept up for ten or fifteen minutes, without inconvenience. A large wax candle supplies the best flame, which being urged by the blast, exhibits two distinct figures; the internal flame is conical, blue, and well defined, at the apex of which the most violent degree of heat is excited; the external is red, vague, and undetermined, and of very inferior temperature to the former.

The substance to be submitted to the action of the blowpipe, which should not be larger than a small pepper corn, must be supported either on charcoal, or a slip of platina or silver foil, or be held in a pair of platina pincers. In the first case it may be placed in a cavity in the charcoal, and another piece laid over it to prevent its being carried off by the blast. The metallic supports are used when the subject of the experiment is intended to be exposed to the action of heat only, and might be altered by contact with the charcoal. If a very intense heat be required the foil may be laid on charcoal. Salts and volatile substances, are to be heated in glass tubes, closed at one end, and enlarged according to circumstances, so as to form small matrasses.

The exterior flame should first be directed on the substance, and when its action is known, then the interior blue flame. Notice should be taken, whether the matter decrepitates, splits, swells up, liquefies, boils, vegetates, changes colour, smokes, is inflamed, becomes obedient to the magnet, &c. (*a*); when the action of heat alone has been ascertained, it will be necessary to examine what further change takes place, by fusing it with various fluxes, and also whether it be capable of reduction to the metallic state.

(*a*) M. Haüy has lately proposed the following ingenious method of rendering very weak magnetic attractions precipitible.

If we conceive the needle to be removed a little from the plane of its magnetic meridian, its directing force will immediately tend to restore it, and with a power proportionate to the size of the angle which the needle makes with the magnetic meridian. Before any substance can act on the needle, it will have to overcome the directing force, as well as the friction at the point of suspension; obstacles which may prevent the effect of very slight attractions from being perceived. To diminish the force opposed to the action of the needle, M. Haüy places a magnetic bar at a certain distance from it, on the same level and in the direction of its axis, but with its poles situated contrary to those of the needle. If we suppose the magnetic bar to be placed to the south of the needle, the south pole of the magnet and the needle will be opposed to each other, and if the magnet be made to approach the needle, the latter will move on its centre towards one side or the other, till an equilibrium is produced between the mutual action of the magnet and needle, and that of the needle and the earth. Coulomb has shewn that in proportion as the needle deviates from its natural position, the increments of power necessary to produce equal effects, are in a decreasing ratio; so that when it has moved through nearly a quarter of a circle, a very small attractive power will be sufficient to influence it. When it is in this position, that is nearly at right angles with the mag-

The three most useful fluxes, are the triple phosphate of soda and ammonia, subcarbonate of soda and borax. These are to be kept ready pulverised, and when used, a sufficient quantity may be taken up by the moistened point of a knife; the moisture causes the particles to cohere and prevents their being blown away, when placed on the charcoal. The flux must be melted into a clear bead, and the substance then placed on it, and submitted, first to the action of the exterior, and then to that of the interior flame. The appearances which ensue must be observed; as,

1st. If the substance be dissolved, and whether with or without effervescence:

2nd. The transparency, and colour of the glass whilst cooling;

3rd. The same circumstances, when cold;

4th. The nature of the glass formed by the exterior flame;

5th. Also, by the interior flame.

6th. The particular appearances with each of the fluxes.

Subcarbonate of soda does not form a bead on charcoal, but with a certain degree of heat is absorbed; it must therefore be added in very small quantities, and a gentle heat used at first, which will promote combination without the absorption of the alkali. Some

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netic meridian, the needle is in its most sensible state; and is affected if any substance containing the most minute portion of iron be presented to it.

Hauy has by this method detected iron in several minerals where its presence was not suspected, or where it was supposed to exist in a state not liable to be affected by the magnet.—Annals of Philosophy, vol. xii. p. 117.

minerals combine readily with very small portions of soda, but difficultly if more be added, and are absolutely infusible with it in great excess; and when the substance has no affinity for this flux, it is absorbed by the charcoal, and no combination ensues.

When the mineral contains sulphur or sulphuric acid, the glass acquires a deep yellow colour, which by the light of a lamp appears red, as if produced by copper.

If the glass bead become opaque as it cools, so as to render the colour indistinct, it should be broken and a part of it mixed with more of the flux, till the colour becomes purer, and distinct. To make the colour more perceptible, the bead may be flattened whilst soft, or drawn out to a thread.

If it be wished to oxidate a metallic substance, combined with either of the fluxes, the glass is first heated intensely, and when fused, gradually withdrawn from the point of the blue flame, and the operation repeated, as often as necessary, using a jet of large aperture. The addition of a little nitre also assists the oxidation. For the reduction of metallic oxides, the glass bead is to be kept in fusion on charcoal, as long as it remains on the surface and is not absorbed, that the metallic particles may collect into a globule. It is then to be fused with an additional quantity of soda, which will be absorbed by the charcoal, and the spot where the absorption has taken place, strongly ignited by a tube with a small aperture. By continuing the ignition, the portion of metal which was not previously reduced, will now be brought to the metallic state, and the process may be assisted, by placing the bead in a smoky flame, so as to cover it with a soot that is not easily blown off.

The beads which contain metals frequently have a metallic splendour, which is most easily produced by a gentle, fluttering, smoky flame, when the more intense heat has ceased. With a moderate heat the metallic surface remains; and by a little practice it may generally be known whether the substance under examination contains a metal or not. But the glass of borax alone sometimes assumes externally a metallic appearance.

When the charcoal is cold, that part impregnated with the fused mass should be taken out with a knife, and ground with distilled water in an agate mortar. The soda will be dissolved; the charcoal will float, and may be poured off; and the metallic particles will remain in the water, and may be examined.

In this manner most of the metals may be reduced.

Action of the Blowpipe on the Earths and Metallic Oxides.

Barya, when containing water, melts and spreads on the charcoal. Combined with sulphuric acid, it is converted, in the *interior* flame, into a sulphuret, and is absorbed by the charcoal, with effervescence, which continues as long as it is exposed to the action of the instrument.

Strontia, if combined with carbonic acid, when held in small thin plates with platina forceps in the *interior* flame, has its carbonic acid driven off, and on the side of the plate farthest from the lamp, a red flame is seen, sometimes edged with green, and scarcely perceptible but by the flame of a lamp. Sulphate of strontia is reduced in the *interior* flame to a sulphuret; dissolve this in a drop of hydrochloric acid, add a drop of alcohol, and dip a thin slip of deal in the solution; it will burn with a fine red flame.

Lime.—The carbonate is easily rendered caustic by heat; it then evolves heat on being moistened, turns paper stained with turmeric brown, and is infusible before the blowpipe. The sulphate is easily reduced to a sulphuret, and possesses, besides, the property of combining with fluor spar at a moderate heat, forming a clear glass. The fluor should be rather in excess.

Magnesia produces, like strontia, an intense brightness in the flame of the blowpipe. A drop of a solution of cobalt being added to it, and then dried and strongly ignited, a faint flesh red colour, scarcely visible by the light of a lamp, is produced.

Magnesia may in this manner be detected in compound bodies, if they do not contain much metallic matter, or a quantity of alumina exceeding that of the magnesia. Some inference as to the proportion of the magnesia may be drawn from the intensity of the colour produced.

All these alkaline earths, when pure, are readily fusible with the fluxes, into a clear, colourless glass, without effervescence; but on adding a further quantity of the earth, the glass becomes opaque.

Alumina combines more slowly with the fluxes than the preceding earths do, and forms a clear glass, which does not become opaque. But the most striking character of alumina is the bright blue colour it acquires from the addition of a drop of nitrate of cobalt, after having been dried and ignited for some time. It may thus be detected in compound minerals where the metallic substances are not in great proportion, nor the quantity of magnesia large.

The following, according to Berzelius, is a ready method of discovering lithia, in any mineral supposed to contain it; it is founded on the facility with which that alkali attacks platina.

Take a morsel of the mineral, about the size of a pin's head, or a small quantity of it reduced to fine powder, and heat it, with an excess of soda, on a slip of platina foil before the blowpipe, and keep it red hot for about two minutes. The stone will be decomposed, the soda will expel the lithia from its combination, and the excess of alkali, becoming fluid at this temperature, will spread over the surface of the foil, and envelope the decomposed mass. The platina round the fused alkaline mass assumes a dark colour, deep and extensive in proportion to the quantity of lithia in the mineral. The platina beneath the alkali is not oxidated, but only in those parts where it is in contact both with the air and the lithia. Potassa destroys the action of platina on the lithia, if it be not in considerable quantity. The metal recovers its brilliancy after being well washed with water and heated to redness.—Annales de Chimie, vol. x. p. 104, note.

Metallic Oxides and Acids.

Arsenic flies off accompanied by its characteristic smell, resembling garlic. When large pieces of white arsenic are heated on ignited charcoal, no smell is perceived. To produce this effect, the white oxide must be reduced by being mixed with powdered charcoal. If arsenic be suspected in a solution, it may be discovered by dipping into it a piece of pure and well burnt charcoal, which is afterwards to be dried and ignited.

Chromium.—Its green oxide exhibits the following properties: it is fusible with *microcosmic salt* (phosphate of soda and ammonia) in the interior flame, into a glass which at the instant of its removal from the flame is of a violet hue, approaching more or less to dark blue or red, according to the proportion of the chromium. After cooling, the glass is bluish green, but less blue than copper glass. In the exterior flame the colour becomes brighter, and less blue than the former. With borax it forms a bright yellowish or yellow red glass in the exterior flame; and in the interior flame this becomes darker and greener, or bluish green.

Molybdic acid melts by itself upon the charcoal with ebullition, and is absorbed. In a platina spoon it emits white fumes, and is reduced in the interior flame to molybdous acid, which is blue, but in the exterior flame it is again oxidated and becomes white. With *microcosmic salt*, in the exterior flame, a small proportion of the acid gives a green glass, which by gradual additions of the acid passes through yellow green to reddish, brownish, and hyacinth brown, with a slight tinge of green. In the interior flame the colour passes from yellow green, through yellow-brown, and brown-red, to black; and if the proportion of acid be large, it acquires a metallic lustre, like the sulphuret, which sometimes remains after the glass has cooled. *Molybdic acid* is but sparingly dissolved by borax. In the exterior flame the glass acquires a grey-yellow colour. In the interior flame black particles are precipitated from the clear glass, leaving it almost colourless when the quantity of molybdenum is small, and blackish when the proportion is large. If to a glass formed of this acid and microcosmic salt a little borax be added, and the mixture fused in the exterior flame, the colour becomes instantly reddish-brown; in the interior flame the black particles are also separated, but in smaller quantity. By long continued heat the colour of the glass is diminished, and it appears yellower by the light of a lamp than by day-light. This acid is not reduced by soda in the interior flame.

Tungstic Acid becomes upon charcoal at first brownish yellow, is then reduced to a brown oxide, and lastly becomes black without melting or smoking. With *microcosmic salt* it forms in the interior flame a pure blue glass, without any violet tinge; in the exterior flame this colour disappears, and appears again in the interior. With *borax*, in the internal flame, and in small proportion, it forms a colourless glass, which by increasing the proportion of acid, becomes dirty grey, and then reddish. By long exposure to the external flame it is rendered transparent; but as it cools it becomes muddy, whitish, and changeable into red when seen by day-light. It is not reduced.

Oxide of Tantalum undergoes no change by itself, but is readily fused with *microcosmic salt* and with *borax*, into a clear colourless glass, from which the oxide may be precipitated by heating and cooling it alternately. The glass then becomes opaque, and the oxide is not reduced.

Oxide of Titanium becomes yellowish when ignited in a spoon, and upon charcoal dark brown. With *microcosmic salt* it gives in the interior flame a fine violet-coloured glass more tending to blue than that from manganese. In the exterior flame this colour disappears. With borax it gives a dirty hyacinth colour.

Oxide of Cerium becomes red brown when ignited. When the proportion is small it forms with the fluxes a clear, colourless glass, which by increasing the proportion of oxide becomes yellowish-green while hot. With *microcosmic salt*, if heated a long time in the internal flame, it gives a clear colourless glass.

With borax, under similar circumstances, it gives a faint yellow green glass while warm, but is colourless when cold. Exposed again for some time to the external flame, it becomes reddish yellow, which colour it partly retains when cold. If two transparent beads, one of the compound with microcosmic salt, the other with borax, be fused together, the triple compound becomes opaque and white. The oxide is volatile, (see Thomson's Chemistry, vol. i. p. 408, 5th edition).

Oxide of Uranium.—The yellow oxide by ignition becomes green or greenish brown. With microcosmic salt in the interior flame it forms a clear yellow glass, the colour of which becomes more intense when cold. If long exposed to the exterior flame, and frequently cooled, it gives a pale yellowish, red-brown glass, which becomes greenish as it cools. With borax in the interior flame, a clear, colourless, or faintly green glass is formed, containing black particles, which appear to be the metal in its lowest state of oxidation. In the exterior flame this black matter is dissolved if the quantity be not too great, and the glass becomes bright yellowish-green, and after further oxidation yellowish-brown. If brought again into the interior flame, the colour gradually changes to green, and the black matter is again precipitated, but no further reduction takes place.

Oxide of Manganese gives with *microcosmic salt*, in the exterior flame, a fine amethyst colour, which disappears in the interior flame. With borax it gives a yellowish hyacinth red glass. When the manganese, from its combination with iron, or any other cause, does not produce a sufficiently intense colour in the glass, a little nitre may be added to it while in a state of fusion, and the glass then becomes dark violet while hot, and reddish violet when cool. It is not reduced.

Oxide of Tellurium, when gently heated, becomes first yellow, then light red and afterwards black. It melts and is absorbed by the charcoal, and is reduced with a slight detonation, a greenish flame and a smell of horse-radish. Microcosmic salt dissolves it without being coloured.

Oxide of Antimony is partly reduced in the exterior flame and spreads a white smoke on the charcoal. In the interior flame it is readily reduced either alone or with the addition of soda. With microcosmic salt and with borax it forms a hyacinth coloured glass. Metallic antimony, when ignited on charcoal, becomes covered with radiating acicular crystals of white oxide. Sulphuret of antimony melts on charcoal, and is absorbed.

Oxide of Bismuth melts readily in a spoon to a brown glass, which becomes brighter as it cools. With microcosmic salt it forms a grey yellow glass, which loses its transparency, and becomes pale when cool. Add a further proportion of oxide, and it becomes opaque.

With borax it forms a grey glass, which decrepitates in the interior flame, and the metal is reduced and volatilized. It is readily reduced by itself on charcoal.

Oxide of Zinc becomes yellow when heated, but whitens as it cools. A small proportion forms with microcosmic salt, and with borax a clear glass, which becomes opaque on increasing the quantity of oxide. A drop of nitrate of cobalt being added to the oxide and dried and ignited, it becomes green. With soda in the interior flame it is reduced, and burns with its characteristic flame, depositing its oxide upon the charcoal. By this process zinc may be easily detected even in the automalite. Mixed with oxide of copper and reduced, the zinc will be fixed and brass be obtained. But one of the most unequivocal characters of the oxide of zinc is, to dissolve it in vinegar, evaporate the solution to dryness, and expose it to the flame of a lamp, when it will burn with its peculiar flame.

Oxide of Cadmium is orange yellow, not volatile, and easily reduced; it gives no colour to borax. (Anales de Chimie, tom. viii. p. 100, new series.)

Oxide of Iron produces with microcosmic salt or borax in the exterior flame, when cold, a yellowish glass, which is blood-red while hot. The protoxide forms with these fluxes a green glass, which by increasing the proportion of the metal passes through bottle green to black and is opaque. The glass from the oxide becomes green in the interior flame, and is reduced to protoxide, and becomes attractable by the magnet. When placed on the wick of a candle, it burns with the crackling noise peculiar to iron.

Oxide of Cobalt becomes black in the exterior, and grey in the interior flame; a small proportion forms with microcosmic salt and with borax a blue glass, that with borax being the deepest. By transmitted light the glass is reddish. By farther additions of the oxides, it passes through dark blue to black. The metal may be precipitated from the dark blue glass by inserting a steel wire into the mass while in fusion. It is malleable if the oxide has been free from arsenic, and may be collected by the magnet, and is distinguished from iron by the absence of any crackling sound when placed on the wick of a candle.

Oxide of Nickel becomes black at the extremity of the exterior flame, and in the interior greenish grey. It is dissolved readily, and in large quantity, by microcosmic salt. The glass while hot is a dirty dark red, which becomes paler and yellowish as it cools. After the glass has cooled, it requires a large addition of the oxide to produce a distinct change of colour. It is nearly the same in the exterior and interior flame, being slightly reddish in the latter. Nitre added to the bead makes it froth, and it becomes red brown at first and afterwards paler. It is easily fusible with borax, and the colour resembles the preceding. When this glass is long exposed to a high degree of heat in the interior flame, it passes from reddish to blackish and opaque, then blackish grey and transparent; then paler reddish grey, and clearer, and lastly transparent, and the metal is precipitated in small white metallic globules.

The red colour seems here to be produced by the entire fusion or solution of the oxide, the black by incipient reduction and the grey by the minute metallic particles before they combine and form small globules. When a little soda is added to the glass formed with borax, the reduction is more easily effected, and the metal collects itself into one single globule. When this oxide contains iron, the glass retains its own colour while hot, but assumes that of the iron as it cools.

Oxide of Tin, in form of hydrate, and in its highest degree of purity, becomes yellow when heated, then red, and when approaching to ignition black. If iron or lead be mixed with it, the colour is dark brown when heated. These colours become yellowish as the substance cools. Upon charcoal in the interior flame, it becomes and continues white; and if originally white, and free from water, it undergoes no change of colour by heating. It is very easily reduced without addition, but the reduction is promoted by adding a drop of solution of soda or potassa.

Oxide of Lead melts, and is very quickly reduced, either without any addition, or when fused with microcosmic salt or borax. The glass not reduced is black.

Oxide of Copper is not altered by the exterior flame, but becomes protoxide in the interior. With both microcosmic salt and borax it forms a yellow-green glass while hot, but which becomes blue-green as it cools. When strongly heated in the interior flame, it loses its colour, and the metal is reduced. If the quantity of oxide be so small that the colour be not perceptible, its presence may be detected by the addition of a little tin, which occasions a reduction of the oxide to protoxide, and produces an opaque red glass. If the oxide has been fused with borax, this colour is longer preserved; but if with microcosmic salt, it soon disappears by a continuance of heat. The copper may also be precipitated upon iron, but the glass must be first saturated with iron. Alkalies or lime promote this precipitation. If the glass containing copper be exposed to a smoky flame, the copper is superficially reduced, and the glass covered while hot with an iridescent pellicle, which is not always permanent after cooling. It is very easily reduced by soda. Salts of copper, when heated before the blowpipe, give a fine green flame.

Oxide of Mercury, before the blowpipe, becomes black and is entirely volatilized. In this manner its adulteration may be discovered.

The other metals may be reduced by themselves, and may be known by their own peculiar characters. (Thomson's Annals, No. lxi. p. 42. et seq.)

I shall conclude this subject in the words of the Professor of Upsal.—"From what has been said, I think it apparent that the blowpipe is an instrument extremely useful, nay necessary, to chemists; for many experiments are daily neglected.—1st. Because they require furnaces and a large apparatus of vessels; yet many of these may easily be performed by means of the apparatus above described.—2d. From the want of time necessary for examining in the ordinary way; whereas the experiments above-mentioned may be finished in a few minutes.—3d. The usual method of examination requires a certain quantity of the matter to be examined, which prevents the examination of such as are scarce or dear; but, in our way, the smallest particle is sufficient. However, the conveniences now described, though of great weight, are attended with this defect, that they do not determine the proportions, or at least point them out but very inaccurately. But the first inquiry to be made is *what* a substance contains, not *how much*, and these trials in small suggest the proper method of instituting experiments at large. These experiments have, besides some advantages over those conducted in crucibles; namely, we can see all the phenomena from beginning to end, which wonderfully illustrates the series of operations, and their causes. Experiments made in crucibles are often fallacious, as the substance of the vessel itself is corroded. We suppose that lime or magnesia, melted with fixed alkali, are united with it in the way of solution, but the globule, when well fused in the spoon, by its transparency permits us plainly to see, that except the siliceous part, it is only mechanically mixed. The most intense degree of heat may in this way be obtained in a few minutes, which is scarcely obtained in many hours in a crucible. This may be sufficient for the commendation of the blowpipe; those who use it will gradually discover more of its valuable properties."——(Bergman's Chemistry, vol. ii. p. 528.)

C. The unhappy frequency with which arsenic has been employed for the most nefarious purposes, renders an infallible mode of detecting its presence, *when in very minute quantity*, a great desideratum in medical jurisprudence.

The following test, recommended by Dr. Marcet, is the most delicate and certain that I am acquainted with; I give it in his own words:

"To the suspected fluid, previously filtered, add first a little dilute nitric acid, and afterwards nitrate of silver till it shall cease to produce any precipitate. The muriatic acid being thus removed, whilst the arsenious acid, (if any, and in whatever state,) remains in the fluid, the addition of ammonia will instantly produce the yellow precipitate in its characteristic form. It is hardly necessary to add that the quantity of ammonia must be sufficient to saturate any excess of nitric acid which the solution may contain."

As the presence of common salt is always probable in cases where this test is used to detect arsenic suspected to be employed as a poison, it is necessary to adhere strictly to the method prescribed. The nitric acid previously added will retain the arsenious acid in solution, whilst the chloride of silver will be precipitated, and must be separated by the filter; the addition of the ammonia will then determine the decomposition of the nitrate of silver, and nitrate of ammonia, and arsenite of silver, will be formed. An excess of ammonia ought to be avoided, but should it inadvertently be added, it may be neutralized by a fresh portion of the nitric acid, cautiously added, which will occasion the re-appearance of the arsenite of silver. Both the nitric acid and the ammonia should be very much diluted.

I subjoin a statement of the characteristic properties of arsenite of silver, from Dr. Marcet's paper already alluded to. (Phil. Mag. vol. xli. p. 122.)

" Its colour is yellow. If, after being well washed in distilled water, it be suffered to stand for some time in an open vessel, it gradually passes to a brown colour; but it does not, like nitrate of silver, become black on continuing this exposure.

" It is readily soluble in dilute nitric acid; it also dissolves on adding an excess of ammonia at the moment of its formation; but after it has been separated and dried, it is no longer sensibly soluble in ammonia.

" If a small quantity of this precipitate be exposed to the heat of a lamp on a slip of lamellated platina, a white smoke arises from it, and metallic silver remains attached to the platina. The reduction of the silver, in the form of a globule, is still more distinct and striking, if a little carbonaceous matter be mixed with the precipitates and the blowpipe applied.

"When the yellow precipitate, inclosed in a tube, is exposed to the heat of a lamp, the white smoke condenses on the cold part of the tube, in minute octohedral crystals of arsenious acid."

The same method is equally applicable to detect the presence of this destructive poison, if it be in the state of *arsenic* acid; but the colour of the precipitate on adding the ammonia will in that case be a reddish brown. It is more likely to be met with in the form of arsenious acid.

It has been objected to this test, that if a phosphate be present its indications are ambiguous, for the colour of phosphate of silver is not much unlike that of arsenite of silver. An experienced eye, however, will readily distinguish between them; the latter being of a brighter yellow than the former, and in serious cases it is to be hoped and expected that none but persons of experience would presume to hazard an opinion.

If the arsenic be in considerable quantity no difficulty in ascertaining its presence can arise; but since even half a grain (perhaps less) of arsenious acid is sufficient to occasion death in a child or a delicate woman, and in collecting the contents of the stomach for examination, it is more than probable that some of the poison may be lost, the precipitate may not contain even half that small quantity, and all attempts to reduce it to the metallic state, or obtain unequivocal proofs of its presence by sublimation, must in that case be hopeless. Recourse should therefore be had to some other test which may serve to confirm or confute the indications of the silver test, and a portion should always be reserved for that purpose.

The best method that I know is to pass a current of sulphuretted hydrogen gas into the suspected solution, when if arsenious acid be present, it will occasion the appearance of a fine lemon-yellow colour through the liquid, but will have no action on phosphate of soda. That substance, however, may prevent the yellow colour from appearing, although arsenious acid be actually contained in the solution; but the addition of a few drops of very dilute pure nitric acid will immediately produce it. If, therefore, both the silver test and the sulphuretted hydrogen concur in indicating the presence of the poison, no reasonable doubt can be entertained respecting it; but it is certainly an additional satisfaction to reduce a portion to the metallic state, or at least to sublime the oxide so as to render its peculiar alliaceous odour distinctly evident, when enough can be collected for the purpose, though that cannot often be expected.

Sulphuretted hydrogen precipitates tartrate of antimony orange, and corrosive sublimate yellowish white, (which, by standing becomes quite white,) and with nitrate of silver they both give white precipitates, so that no confusion can be occasioned by either of these substances. I find that sulphuretted hydrogen gives a decided yellow colour to an ounce measure of distilled water, containing one drop of a saturated solution of arsenious acid equal to $\frac{8}{100}$dths of a grain of the solid acid, or about $\frac{1}{5700}$dths of the whole weight of the solution. Two or three drops of phosphate of soda prevented its action, but a little very dilute acetic acid immediately produced the yellow colour.

If distilled vinegar be employed, care must be taken previously to ascertain its purity. It frequently contains a small portion of lead, derived from the vessels used in its distillation, and will in that case be sensibly affected by sulphuretted hydrogen.

D. In the great progress which chemistry has made within a few years, one of its most important steps towards perfection as a science, is the establishment of the Atomic Theory, and since a knowledge of the principles on which it is founded is important to the practical analyst, (for it affords him an easy and almost infallible test of the accuracy of his experiments,) I shall endeavour to lay a short sketch of it before the reader.

If iron and sulphur be fused together in proper proportions, the result is a chemical compound, every particle of which, however minutely divided, will be found to contain a portion of each ingredient. Mechanical division, though theoretically infinite, cannot practically be carried beyond certain limits: but, since the minutest particle it is capable of presenting to us, shews no difference in composition from that of the entire mass, the inference is irresistible that could we proceed to the ultimate term of material divisibility, we should still have the same result, and that consequently the union between the iron and sulphur, has been effected by the combination of their minutest particles, or atoms, which thus are the integers whose sum is the compound mass obtained. Whatever portion we take of this mass, it must contain a certain number of the atoms of each substance, and although we know nothing of their actual number, still we obtain by analysis the proportion that the atoms of one kind bear to those of the other; or, supposing the compound to contain an equal number of each, the proportionate weights of the atoms themselves.

In those cases where only one known compound of two elements exists, it is most simple to consider it as formed of one atom of one element and one atom of the other; thus water is the only known compound of oxygen and hydrogen, 100 parts contain 88.24 oxygen, + 11.76 hydrogen, or one of the latter to 7.5 of the former, and supposing them to be united atom to atom, those numbers become the symbols to represent the relative weights of their respective atoms (*a*).

When more than one compound is formed by the same elements, if we suppose the first, or simplest to be composed of 1 atom of one substance, and 1 atom of the other, the next must be 1 and 2, or 1 and 3, and so on; or always, the number of atoms of the substance which combines in more than one proportion,

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(*a*) Dr. Thomson calls oxygen 1, and hydrogen .0125, and adopts Dr. Prout's hypothesis in calculating his numbers generally (see the fifth edition of his Chemistry, passim)

If the weights of atoms be deduced from the specific gravities of the gases and their combinations by volume, they will be found equally consistent with the theory. Thus, the specific gravity of hydrogen gas is 0.0737, and that of oxygen gas 1.106, atmospheric air being 1.000, and one volume of hydrogen condenses half a volume of oxygen, and $.0737 : 1 :: \frac{1.106}{2} : 7.5$.

Since the volume of hydrogen is double that of the oxygen, we msut suppose either that its particles are twice as large as those of oxygen, or at twice as great a distance from each other, or else that two atoms of hydrogen combine with one of oxygen All this however need create no confusion; for, though the term *atom* be useful in tracing the theory to its source, yet all that is really important, are the constant tangible proportions observed in chemical compounds, and, as the author of the article "Atomic Theory" in the supplement to the Encyclopedia Britannica observes, a "number of atoms constantly and invariably united together, constitute a compound atom, about which we may reason, as accurately and as justly, as we could do about the atoms themselves."

must in the second, third, &c. compound, be a multiple by a whole number of their number in the first; the number of atoms of the other substance remaining constant. For instance, sulphur unites to tin in two proportions, the first consists of tin 55 + sulphur 15; the second of tin 55 + sulphur 30. Again, tin unites in two proportions with oxygen; the first contains tin 56 + oxygen 7.5; the second, tin 55 + oxygen 15. But if the law hold, it also follows, that that proportion, or some multiple or division of it, which a substance observes in uniting with any *one* other substance, it must likewise observe in its combinations with *all* other substances. Thus, as sulphur unites with tin in the proportion of 15, it must also unite in the same proportion with copper, with potassa, with hydrogen, &c. &c.

(*a*) Sulphuret of copper contains sulphur 15 + copper 60; sulphuret of potassa, sulphur 15 + potassa 45; sulphuretted hydrogen, sulphur 15 + hydrogen 1; and every one of these bodies must combine with all others in the proportions expressed by their respective numbers. Accordingly 60 copper + 7.5 oxygen form oxide of copper, and 60 + 15 form peroxide. The combinations of sulphur with oxygen present an apparent anomaly; the first consists of sulphur 15 + oxygen 15; the second of sulphur 15 + oxygen 22.5, numbers which are not as 1:2 but as 2:3; but the first contains just twice as much oxygen as is found in an atom of the protoxides of tin and copper, or of water; it is reasonable therefore to consider it as

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(*a*) In proportionate numbers, some standard must of course be assumed, to which they all refer: in the present case, the standard is hydrogen, which is taken as unity.

formed of one atom of sulphur combined with two atoms of oxygen, and that there may be another more simple compound of 1 of sulphur = 15 + 1 of oxygen = 7.5, although its existence has not yet been experimentally demonstrated. Thus, the numbers which denote the combinations of sulphur and copper with each other, also denote the proportions in which they respectively combine with oxygen, and the same holds good with regard to their combinations with all other bodies, copper always uniting in the proportion of 60, and sulphur in that of 15, and the combinations of all other substances may in like manner be expressed by certain definite and invariable symbols.

The *compound* atoms must also observe similar proportions, and we accordingly find that sulphuric acid, which is composed of sulphur 15 + oxygen 22.5 = 37.5, combines with 45 parts of potassa to form sulphate of potassa, and 75 parts of sulphuric acid combine with 75 of peroxide of copper, to form sulphate of copper. This latter salt furnishes an instance of the combinations of the atoms, in multiples of the numbers representing them; it consists of 2 atoms of sulphuric acid (37.5 × 2) and 1 atom of peroxide of copper (60 + 15) (*a*).

When two neutral salts are mutually decomposed, the new compounds are neutral. Thus, sulphate of potassa being poured into nitrate of barya, a double decomposition ensues, and we obtain sulphate of barya which is precipitated, and nitrate of potassa which

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(*a*) This is an illustration of Berzelius's law, that the quantity of acid in salts is proportionate to the quantity of oxygen in their bases. Peroxide of copper contains two atoms of oxygen, and accordingly takes two atoms of sulphuric acid to form sulphate of copper.

remains in solution, and both perfectly neutral. Sulphate of potassa, as we have just seen, consists of 37.5 sulphuric acid + 45 potassa, = 82.5, and nitrate of barya of nitric acid 50.65 + barya 72.5 = 123.15. When these salts are dissolved in distilled water, and their solutions mingled, the 37.5 of sulphuric acid leave the potassa and unite with the 72.5 of barya, forming 110 of sulphate of barya, and the 50.65 of nitric acid, combine with the 45 of potassa to form 95.65 of nitre: and 110 + 95.65 = 205.65, the original weight of the salts employed. Similar phenomena occur, if solutions of sulphate of potassa and nitrate of lead be presented to each other, and generally in all cases of double decompositions; whence we obtain the important law first observed by Richter, that when two neutral salts act on each other, the quantity of base disengaged from either of them, is in the exact proportion required to saturate the acid disengaged from the other.

It is evident that a series of numbers may be found to represent the respective proportions in which the atoms of all bodies, and consequently the bodies themselves combine. Such a series has been given by Mr. Dalton in his new system of Chemical Philosophy, by Sir Humphry Davy in his System of Chemistry, by Dr. Wollaston on his scale of Chemical Equivalents, and by Berzelius and other experimentalists.

Sir Humphry Davy with Dalton assumes hydrogen for his unit as being the substance that combines in the smallest proportion, and he denotes oxygen by 7.5. Dr. Wollaston makes oxygen the standard, calling it 10, and hydrogen 1.333. It is quite indifferent which we adopt, a very simple process reconciles them; for as 7.5 are three-fourths of 10, to reduce Davy's numbers to Wollaston's we have only to add one-third, or to reduce Wollaston's to Davy's, deduct one-fourth. Thus, Davy gives 15 as the number for sulphur, and $15 + 5 = 20$ the number assigned it by Wollaston, and vice versa $20 - 5 = 15$.

I refer the reader for fuller details respecting the atomic theory to Mr. Dalton's original work, "The new system of Chemical Philosophy," and to an article by Dr. Thomson in the second volume of the Annals of Philosophy, p. 32, in which the outlines of Dalton's system are presented; to Davy's Elements of Chemical Philosophy; to the Supplement to the fourth and fifth editions of the Encyclopedia Britannica; and to Dr. Wollaston's paper in the Philosophical Transactions for 1814, where he will find the data on which the synoptic scale of chemical equivalents is constructed, and a description of that elegant and valuable instrument.

E. *Selenuretted Hydrogen.*—The number of the Annales de Chimie, containing the continuation of Berzelius's experiments on selenium, not having been received when that part of our subject went to press, I add the further details connected with it in this place.

Water, deprived of its air, readily dissolves selenuretted hydrogen, of which it takes up a larger quantity than of sulphuretted hydrogen; the solution is colourless; but after some minutes exposure to the air, it becomes opalescent, reddish on the surface, and deposits selenium; and at last is completely decomposed: it has a hepatic flavour and slight odour, reddens litmus, and stains the skin of a permanent brown colour, not removeable by water.

A very small portion of nitric acid does not decompose the gas, and the solution retains its power of precipitating the metallic salts, (all of which it throws down) for several hours after its addition. Moistened paper, if put in contact with selenuretted hydrogen gas acquires a red stain throughout; and a piece of wood similarly treated becomes coloured, to some depth below the surface: the whole substance of a tube of Caoutchouc, which had been used to conduct the gas, acquired a fine red colour.

The effects of this gas on the tracheal artery, and the lungs, are so violent as to be in some degree dangerous. It first affects the nose with an odour exactly similar to that of sulphuretted hydrogen, which is soon succeeded by a painful sensation, like that occasioned by fluosilicic acid gas, but more acute, over all the parts that have come in contact with the gas; the eyes become inflamed, and the sense of smell is for a time totally destroyed. Its action on the olfactory organs is so violent, that a small bubble, not larger than a pea, deprived Berzelius of the power to distinguish the smell of caustic ammonia, when he held a bottle containing a strong solution of it to his nose. The effects on another occasion were more serious. Berzelius describes them as follows:—"I had first a pricking sensation (piquante) in the nostrils; my eyes became red, and symptoms of catarrh (rhume) began to appear. After half an hour I was attacked with a very painful dry cough, which having continued a considerable time, brought on expectoration, the matter of which had the flavour of the vapours of a boiling solution of corrosive sublimate. The symptoms were at length removed by applying a blister to the chest."

Berzelius analysed selenuretted hydrogen by passing a current of the gas through a solution of nitrate of silver, deprived of air by long boiling. The black precipitate being thoroughly dried was dissolved in pure nitric acid, and converted into chloride of silver, by pouring the solution into dilute hydrochloric acid. From this the quantity of silver was obtained, which being known, the oxygen combined with the metal in the state of nitrate, and consequently the hydrogen necessary to reduce it to the metallic state, as well as the weight of the selenium of the selenuret of silver, was easily calculated. Suppose the selenuret of silver weighed 100 grains, and that when treated as above, it gave 97.66 grains of chloride of silver, = 73.5 grains of silver. The selenuret then contained 26.5 per cent. of selenium. But 73.5 grains of silver require 5.36 of oxygen to become oxide of silver, and this quantity of oxygen combines with .714 of hydrogen.

Selenuretted hydrogen therefore contains,

Selenium	26.5
Hydrogen	0.714
	27.214

Or per cent.

Selenium	97.38	37.48
Hydrogen	2.62	1.00
	100.00	

Selenuretted hydrogen, like sulphuretted and telluretted hydrogen, acts the part of an acid in combining with those bases, whose affinity for oxygen is superior to that of hydrogen: with the others it forms metallic selenurets. The soluble hydro-selenurets have the taste, and in some measure the odour of the hydro-sulphuret of potassa, but their colour is red, or deep orange, rather resembling that of the hydrotellurets, but yellower.

The best method of obtaining the hydroselenurets, is to pass the gas, arising from the decomposition of selenuret of iron, by hydrochloric acid, into a solution of the base in water, in a Woulf's apparatus. The selenuretted hydrogen is more rapidly and compleatly absorbed by the base, than sulphuretted hydrogen would be, and less of the gas escapes.

The hydroselenurets are decomposed by contact of the air. Those whose base is alkaline, let fall pure selenium.

The danger attending experiments on selenuretted hydrogen prevented Berzelius from obtaining any of the hydroselenurets in a dry state, except selenuret of ammonia. Selenuretted hydrogen and ammonia, on being mixed together, form a white cloud, which soon condenses into a pale red mass, without any crystalline appearance, and this, when dissolved in water, gives a deep red solution.

Barya, strontia, lime, and magnesia, all give soluble hydroselenurets. Hydrate of magnesia diffused through water is readily dissolved by an excess of the gas. Hydroselenuret of ammonia throws down a flesh-coloured precipitate from solutions of the earthy hydroselenurets, except that of alumina, with which it gives a deep red precipitate.

All the metallic solutions are precipitated by the alkaline hydroselenurets; the precipitates from the salts of zinc, manganese, cerium, and probably uranium, are hydroselenurets; they soon decompose by access of air, their pale red colour becoming much deeper. The salts of the other metals are reduced to the state of metallic selenurets, and their precipitates are black or deep brown, and exhibit a metallic lustre when strongly compressed with a piece of polished hematite.

M. Berzelius closes his account of the properties of selenium and its compound with some general observations, the substance of which I lay before the reader, who will form his own opinion of their force.

The existence of a body whose properties are intermediate between the non-metallic combustibles and the metals, is an interesting phenomenon. Whilst it possesses some of the distinguishing characters of the metals, as lustre, it is deficient in others equally essential, as the power of conducting electricity and heat; indeed, as there is no absolute line of demarcation between the chemical characters of these bodies, it is not likely that there should be one between their external. Selenium is more analogous to sulphur than to any other body, and after sulphur it most resembles tellurium; so that its properties place it between these two bodies, and it must depend on them whether it is to be classed with the metals, or with the simple non-metallic combustibles. It is indifferent in which of the two classes we place it, their limits being so vague, and selenium partaking in so great a degree of the characters of both, that it may with equal propriety be assigned to either. Metallic lustre and high specific gravity have been considered as properties characteristic of the metals, the last is done away with by the discovery of the bases of the alkalies; lustre therefore only remains, and if sulphur and phosphorus were possessed of it they would probably be placed with the metals. As selenium possesses this property in a very high degree, and as it must, at all events, belong to one of these classes, Berzelius thinks it should in preference be placed with the *electro-negative* metals, that is, those which produce acids; it would begin a series forming the transition from sulphur and phosphorus to arsenic.— Three substances, chlorine, iodine, and fluorine have lately been added to the number of the simple combustibles, two of which may with equal, if not with greater propriety be considered as oxides hitherto undecomposed, and the existence of the third is problematical. To render their simple nature more probable, their supposed analogy with sulphur and phosphorus has been insisted on. It is clear that that analogy will be strengthened or enfeebled, in proportion as other bodies, analogous to these two, are discovered and compared with them. For this reason we shall compare selenium with sulphur, chlorine, iodine, and some other substances.

Sulphur and selenium, on one hand, combine with the metals, and the compounds, which generally preserve some of the external characters of metals, also retain the combustibility of their bases. Sulphuret and selenuret of potassa are soluble in water, which they decompose, and form hydrosulphurets and hydroselenurets. Chlorine and iodine, on the other hand, also combine with the metals; but their compounds have the same general characters with the anhydrous sulphates, phosphates, and arseniates. The bases, at least the most combustible, have lost their combustibility. The chloride and iodide of potassium and sodium do not attract oxygen, do not decompose water, and do not produce hydrochlorates and hydriodates; unless it be pretended that the chlorides of potassium and sodium, for example, decompose water with the production of cold, and those of calcium and baryum with the evolution of heat. On the contrary, the chlorides of copper, tin, and gold, (and many other metals, which in other circumstances do not decompose water, either alone, or sulphuretted, or mixed [*mêlés*] with strong acids,) do decompose water and form hydrochlorates. There is, therefore, no analogy between sulphur and selenium on the one hand, and chlorine and iodine on the other, since the phenomena they give rise to are entirely different.

Sulphur, selenium, and tellurium combine with hydrogen, and form peculiar, gaseous, weak acids. It has long been observed that the combinations of sulphur and tellurium with hydrogen have very strong analogies, notwithstanding the difference in their chemical and physical properties. A third body is now discovered, whose compound with hydrogen has the same odour, taste, and properties as those of the two former. This class of acid bodies gives with the oxides which they do not decompose, particular salts, in which the taste and odour of the acids predominates; and with the other oxides they form water, and compounds with their bases. Hence we may presume that the hepatic smell and taste, far from being peculiar to sulphur, are properties common to this class of acids and their compounds, and as essential characteristics of the hydrogenated acids and their salts with alkaline bases, as a sour taste is of the strong oxygenated acids, and a saline one of the neutral compounds they form with the alkalies.

If we extend these remarks, we find that the salts formed by the oxygenated acids, whose names terminate in *ous*, with alkaline bases, have a peculiar taste, by which the acid may be recognized, as the sulphites, and phosphites. Moreover, the oxygenated acids, which are very weak and indistinctly acid, as the tungstic, stibiic oxide of tellurium, &c. impart a metallic flavour to their combinations with the alkalies; so that each class appears to have some general common properties by which the class may in some measure be known. Chlorine and iodine also combine with hydrogen, but the acids they form are very powerful, and have the pure, distinct, acid odour and taste. These acids possess the peculiar property, by means of their hydrogen, of reducing potassa and soda, and of forming chlorides and iodides which have precisely the saline taste of the salts, formed by the strong oxygenated acids with alkalies; on the other hand, the hydrogen of those acids does not reduce the oxide of copper, bismuth, gold, &c. but they combine with them without decomposition.

The analogy then even between these hydrogenated acids and those mentioned above is absolutely null.—Berzelius (the reader will please to remember the whole of these observations are his) adds, "I have thought it right not to omit these comparisons, because they add to the circumstances, which sooner or later will give us more satisfactory elucidations on the nature of the muriatic, iodic, and fluoric acids."

The analogy between sulphur and selenium holds also in their combinations with oxygen, inasmuch as each forms acids with it of little volatility; however, the analogies between these acids are not so perfect as those between their bases. Sulphuric acid belongs to the numerous class of acids which contain three atoms of oxygen, and consequently combines in the manner of those acids. Selenic acid, on the contrary, belongs to the less numerous class, which without having their names terminated in *ous*, yet contain only two atoms of oxygen, and in this respect has a strong analogy with boracic and carbonic acid; like them it does not form neutral salts with the alkalies. In the salts, when the acid contains twice as much oxygen as the base, the alkali is the re-agent, (reagit) and in those where the acids contains four times as much, the action is owing to the acid. The same phenomena are observed in the borates and the carbonates. Boron and carbon, however, have no analogy with selenium. Boron, indeed, may be combined with the alkalies, but I do not know that boruretted hydrogen or any borurets, analogous to the metallic sulphurets and selenurets, have ever been formed. All the world knows that carbon enters into no combination with the alkalies, and only in very small quantities with the metals; and lastly, that hydruretted carbon has neither an hepatic odour nor taste, nor possesses any acid properties.

Selenium has no analogy in chemical properties with arsenic and phosphorus; it follows the general laws of combination of oxidated bodies, from which the others so remarkably depart. Their compounds with hydrogen, although possessing many of the properties of the gases which contain a large quantity of hydrogen, are not hepatic, and have no acid characters. Arsenic may be said to be to phosphorus, what selenium is to sulphur; but for the rest there is little analogy between these two pairs of bodies.

The reader is probably not *quite convinced* by the above, that selenium is a metal, or chlorine a compound.

As the subject is new, and an additional example of the analysis of a mineral by so able an experimenter as M. Berzelius must be useful, I subjoin his account of that of a supposed ore of tellurium from Sweden, from which he has succeeded in obtaining selenium.

The colour of the mineral is lead grey; its lustre metallic, fracture granular, texture sub-crystalline, (sous-crystalline); it is soft, and yields to the knife; the cuttings have the brilliancy of silver; it is impressed by the hammer.

Before the blowpipe it fuses, and exhales a strong odour of radishes, leaving a small grey metallic button, which continues to give out the same odour for a considerable time; it colours borax copper-green, and a brittle metallic button of selenuret of silver separates. Cold water poured into a solution of the mineral in boiling nitric acid throws down a white precipitate of seleniate of silver, whence it was probably supposed to be an ore of tellurium.

The ore is mixed with carbonate of lime, and black particles, which have a metallic brilliancy when scratched with the knife; fuse with difficulty before the blowpipe, and exhale the smell of selenium; they colour borax copper-green, and give no trace of silver.

a.—100 parts of the purest portions of the mineral carefully selected were dissolved in boiling nitric acid, the solution diluted with boiling water, and filtered; the clear liquor gave a precipitate with solution of common salt, and the matter which remained on the filter was washed with boiling diluted nitric acid, as long as the washings were rendered turbid by hydrochlorate of soda.

The chloride of silver, after being washed, dried, and fused weighed 50.7 parts, equal to 38.93 of silver. The substance remaining on the filter consisted of silica and stoney matter, and weighed, after being heated, 4 parts.

b.—The liquid from which the silver had been separated was precipitated by sulphuretted hydrogen gas: the precipitate re-dissolved in aqua regia, and the solution concentrated, till the nitric acid was entirely decomposed. It was then diluted with water, and sulphite of ammonia added, when the liquid gradually became turbid, and acquired a cinnabar red colour. After some hours it was boiled and small portions of sulphite of ammonia added from time to time. The boiling was continued two hours in order to precipitate the whole of the selenium. Collected, dried, and heated nearly to fusion on the filter, it weighed 26 parts.

c.—From the liquid, separated from the selenium, and deprived of its sulphurous acid by boiling, subcarbonate of potassa threw down a green precipitate, which when washed, dried, and heated red, was converted into black oxide of copper, and weighed 27 parts, equivalent to 21.55 of copper. This oxide, dissolved in hydrochloric acid, gave a blue solution with an excess of ammonia. The alkaline liquor from which the carbonate of copper had been separated, still retained a greenish tinge; it was concentrated and slightly acidulated with hydrochloric acid, and a further precipitate of 1.5 part of copper separated by a plate of iron, which makes the whole of the copper 23,05.

The liquid precipitated by sulphuretted hydrogen, (*b*) was deprived of the excess of gas by boiling, and mixed with caustic ammonia, which threw down a yellowish precipitate, weighing, when dried, 1.8 parts, and was a mixture of oxide of iron with a little alumina. The remaining solution was mixed with subcarbonate of potassa in excess, and evaporated to dryness. The saline mass, re-dissolved in water, left a white earth, which, heated red, weighed 3.4 parts. Sulphuric acid, mixed with this earth, occasioned an effervescence, and by evaporation became gelatinous, and deposited silica; it appeared also to contain magnesia, but it was not particularly examined, as these earths were evidently foreign to the ore.

The results of the analysis then are

Silver	38.93
Copper	23.05
Selenium	26.00
Earthy and foreign substances .	8.90
Loss	3.12
	100.00

The great loss must be partly attributed to the carbonic acid of the carbonate of lime; still more to selenium, which it is difficult to separate entirely, and partly to the loss unavoidable in these sort of experiments.

M. Berzelius proposes to call this mineral Eukairite (from ευκαιροσ, opportunus) from the fortunate discovery of the mineralogical situation (gisement) of selenium, at the moment he had finished his experiments on that interesting substance. This mineral appears, on the authority of M. Hisinger to come from an old mine, now abandoned, at Skrickerum in the parish of Tryserum, in Smoland; specimens of it are occasionally found in old collections, under the name of native bismuth, from Skrickerum. Berzelius found a fine specimen of Eukairite, in the collection of the College of Mines, at Stockholm. It is surrounded with black, or dark green serpentine, penetrated at its point of contact with the Eukairite, by selenuret of copper.

He has also found selenuret of copper in carbonate of lime.

F. *Volatility of Bismuth.*

From some late experiments by M. Chaudet, it appears, that perfectly pure bismuth, when heated in a luted crucible, to 30° of Wedgewood's pyrometer, under charcoal powder, is completely volatilized. (Annales de Chimie, vol. ix. p. 397.)

G. *Separation of Nickel and Cobalt.*

In a paper read to the Academy of Sciences at Paris, in August 1818, M. Laugier proposes the following method, as preferable to all others, for separating nickel and cobalt.

1. Roast the ore to separate the arsenic as completely as possible.
2. Dissolve the residuum in nitric acid, and evaporate the solution to separate the oxide of arsenic.
3. Pass sulphuretted hydrogen gas through the solution, till all the arseniates are decomposed, and the copper thrown down.
4. Boil the solution to drive off the excess of sulphuretted hydrogen, and then precipitate all the metals by carbonate of soda.

5. Digest the carbonates in oxalic acid to separate the iron, and dissolve the oxalates of nickel and cobalt in ammonia; filter, and leave the solution at rest exposed to the air: it gradually loses its fine violet blue colour and becomes red, at the same time, the oxalate of nickel precipitates of a deep green colour, which is to be washed with repeated portions of warm water, to remove any little oxalate of cobalt that may have been carried down with the nickel, and the washings added to the red ammoniacal solution which now contains nothing but the cobalt. (Annales de Chimie, vol. ix. p. 267.)

H. *Oxymuriate of Lime.*

Dr. Thomson has lately examined the salt known by this name, and which is much used in the modern method of bleaching, with a view to determine its composition and nature. He dissolved 50 grains in water, and converted the insoluble portion into sulphate of lime; when heated red it weighed 27.8 grains, indicating 11.68 of lime.

The solution, which reddened turmeric; and consequently held some lime dissolved, was mixed with sulphuric acid, evaporated to dryness, and heated red; the sulphate of lime weighed 31.5 grains, equivalent to 13.23 of lime.

Another 50 grains, dissolved in water, and precipitated by nitrate of silver, gave 55 grains of chloride of silver, indicating 13.56 of chlorine.

13.56 of chlorine, require 10.92 of lime, therefore the 50 grains are composed of

1. Undissolved portion, lime		11.68
2. Dissolved portion,	1 chlorine	13.56
	2 combined lime	10.92
	3 uncombined ditto	2.31
	4 water & impurities	11.53
		50.00

1160 grains of the dry oxymuriate, were submitted to heat in a glass retort, connected with a proper apparatus to receive the gas evolved over water. Pure oxygen came over for some hours, the whole quantity of which amounted to 164 cubic inches. The dry salt in the retort had lost its smell, and its action on vegetable colours; and when digested in water a solution of common hydrochlorate of lime was obtained. "I conclude," says Dr. Thomson, "from this experiment, that in the bleaching salt the chlorine was united, not to calcium, but to lime, and that, therefore, it is in reality, a chloride of lime, as it has hitherto been supposed to be; when it is heated, the lime parts with its oxygen, and is converted into calcium, and the chloride of lime, becomes a chloride of calcium. Of course it loses its peculiar properties, and when dissolved in water, is nothing else than a muriate of lime."

Dr. Thomson finds also that chlorides of barya, strontia, potassa, and soda, may also be formed, by double decomposition from chloride of lime, and he thinks it probable that many of the metallic oxides, are capable of forming chlorides likewise. (Annals of Philosophy, vol. xiii. p. 182.)

Since 50 grains of the bleaching salt contain 10.92 of combined lime, 1160 must contain 253.34 = 71.5 of oxygen; 100 cubic inches of oxygen gas weigh 33.75

grains, therefore 71.5 grains are equal to 211 cubic inches. There is a deficiency of oxygen obtained in the experiment of 47 cubic inches. Probably the whole of the chloride was not decomposed.

I. *Wodanium.*

" In our number for January, we announced the discovery of a new metal by Lampadius, which he has distinguished by the name of Wodanium: we shall now translate the account of this new metal which Lampadius has himself published.

Our venerable mine superintendant, Von Trebra, has had in his possession for several years a metallic mineral from Topschau, in Hungary, under the name of a cobalt ore. But as it gives no blue colour, I got it from him in order to make some further trials on it. I could detect in it no cobalt; but found in it 20 per cent. of a new metal united with sulphur, arsenic, iron, and nickel.

" This metal has a bronze yellow colour, similar to that of cobalt glance; and its specific gravity is 11.470.

" It is malleable; its fracture is hackly; it has the hardness of fluor spar; and is strongly attracted by the magnet.

" It is not tarnished by exposure to the atmosphere at the common temperature; but when heated it is converted into a black oxide.

" The solution of this metal in acids is colourless; or at least has only a slight wine-yellow tinge. Its hydrated carbonate is likewise white. The hydrate of it, precipitated by caustic ammonia, is indigo blue.

" Neither the alkaline phosphates nor arseniates occasion any precipitate, when dropped into a saturated solution of this metal in an acid: neither is any precipitate produced by the infusion of nut-galls. A plate of zinc throws down a black metallic powder from the solution of this metal in muriatic acid. Prussiate of potash throws down a pearl-grey precipitate, &c.

" Nitric acid dissolves with facility both the metal and its oxide, and the solution yields colourless needle-form crystals, which readily dissolve in water.

" As the names of the planets have been already all applied to newly discovered metals, I have, in imitation of Berzelius, had recourse to the old German mythology, and give the metal the provisional name of *Wodan*, or *Wodanium*. My worthy friend Breithaupt, classes the mineral that contains this new metal among the pyrites, and gives it the name of Wodan pyrites (*Wodan-kies*.) He gives the following description of this mineral.

" Wodan pyrites has the metallic lustre, and is shining or glistening.

" Its colour is dark tin-white, passing into grey, or into brown. Hitherto it has occurred only massive; and in that state it is full of cavities.

" The fracture is uneven, and either small or great granular: fragments indeterminate angular, with edges not peculiarly sharp.

" Harder than fluor spar; but softer than apatite.

" Brittle. Easily frangible.

" Specific gravity, 5.192.

" Lampadius informs us, in the letter of which the preceding paragraphs contain the translation, that he intends to publish a full account of the new metal and its ore in the Transactions of the Mineralogical Society of Dresden." (Gilbert's Annalen de Physik, lx. 99, for September, 1818. Annals of Philosophy, vol. xiii. p. 232.

K. *Method of procuring Meconic Acid.*

"The infusion of opium, from which the morphia had been precipitated by means of ammonia, was evaporated to the consistence of a syrup, and left in a state of rest; but no crystals would form in it. It was then diluted with 16 ounces of water, and mixed with 1 ounce of caustic ammonia. As no precipitate appeared after the interval of an hour, the liquid was heated to drive off the excess of ammonia. When heated to the temperature of 122°, it became muddy, and 15⅓ grains of impure morphia were precipitated. The liquid being freed from this precipitate and from the excess of ammonia, muriate of barytes was poured into it as long as any precipitate fell. The precipitate, being collected and dried, weighed seven drams, and was Serturner's meconate of barytes. To obtain the meconic acid from this salt, M. Choulant triturated it in a mortar, with its own weight of glassy boracic acid. This mixture being put into a small glass flask, which was surrounded with sand in a sand pot in the usual manner, and the heat being gradually raised, the *meconic acid* sublimed in the state of fine white scales, or plates."

Properties of Meconic Acid.

"It has a strong sour taste, which leaves behind it an impression of bitterness.

"It dissolves readily in water, alcohol, and ether.

"It reddens the greater number of vegetable blues, and changes the solutions of iron to a *cherry-red* colour. When these solutions are heated, the iron is precipitated in the state of protoxide." (Annals of Philosophy, vol. xiii. p. 230.)

L. *New Researches on Oxygenated Water.*

In continuing his researches on this subject, M. Thenard placed 1200 parts of water containing only 3½ times their volume of oxygen, under an exhausted receiver, above a basin almost full of sulphuric acid; the water soon froze, and in some days was reduced to 30 parts. The water, instead of 3½ volumes, then contained 41 volumes of oxygen, and Thenard conceives it might have been much further oxygenated had the quantity permitted him to continue the evaporation, for he succeeded in combining an acid liquid with 120 volumes of oxygen, which even still continued to absorb it, with the same ease as at first, and scarcely gave any off, by the action of an alkali. At what point, he asks, will the absorption stop? Will it be, when the oxygen equals half of that contained in the water, or its whole quantity?

Water containing 41 volumes of oxygen possesses the following properties:

It is insipid, inodorous, colourless, and has no action on litmus; it freezes, and evaporates in a vacuum without decomposition. A temperature of 212° soon disengages all its oxygen, and the same effect is produced by charcoal, by the peroxides of manganese, cobalt, and lead, by the oxides of silver and platina, and by metallic platina, osmium, silver, gold, palladium, rhodium, and iridium, when minutely divided. The effervescence is almost always very brisk, and in some cases, the metallic oxide parts with its own oxygen at the same time that it disengages the oxygen of the water: the metals never become oxidated in the process. When oxide of silver is placed in contact with oxygenated water, instead of the temperature being reduced, by the disengagement of the oxygen, as we should expect from theory, heat is evolved, and to such an extent that Thenard thinks it would raise a very highly oxygenated liquid to the boiling point; several peroxides produce the same effect. The cause of these phenomena is still hidden in obscurity. (An. de Ch. vol. ix. p. 441.)

Since the preceding note was published, Thenard has obtained water, containing more than 400 times its volume of oxygen. It possessed the following properties:

When placed on the skin, it soon attacked the epidermis, whitened it, and occasioned a violent pricking sensation. Its taste was both astringent and bitter, and somewhat resembled that of emetic tartar.

Some drops of the water being put into a tube, and oxide of silver added to it, a violent effervescence took place, and the tube became so hot, that it could not be held in the naked hand.

Lastly, a large quantity being put into a glass, and some recently precipitated, and still moist, oxide of silver dropt suddenly into it, a slight explosion ensued. (An. de Ch. vol. x. p. 114.)

The following note appeared in the Annales de Chimie, for March, 1819, (vol. x. p. 335), and is highly interesting, as containing the completion of M. Thenard's very curious researches on this subject.

It will be seen that the result is a new, and hitherto unsuspected, *definite* combination of oxygen and hydrogen, in which the quantity of the former is just double that which is contained in water. It is the water, therefore, and not the acid, as M. Thenard first imagined, that is oxygenated, the effect of the latter being only to render the union between the water and oxygen more stable. I understand M. Thenard still considers the phenomena to be referable to electrical energies, but it would be improper to anticipate his reasoning, which no doubt will be as acute and satisfactory, as the experiments which led to these extraordinary facts have been ingenious. I give the note as it is published in the journal above mentioned.

New results on the combination of Oxygen with Water.

By M. THENARD.

(Presented to the Academy of Sciences, Monday, March 29th, 1819.)

I have at length succeeded in saturating water with oxygen, and find it to contain 850 (*a*) times its volume of oxygen, or twice that which is proper to it, in its natural state. Its properties are altogether peculiar; amongst which the most remarkable, are the following:

Its density is 1.455, and when poured into common water, it is seen flowing through it like syrup, although very soluble in that fluid. It attacks and

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(*a*) This must be a mistake,—the quantity of oxygen in common water, in the form of gas, would be about 650 times its volume; consequently 850 should be, at least, 1300.

whitens the epidermis, almost instantly, and produces a pricking sensation, more or less durable in proportion to the quantity of liquid applied to the skin; if a large quantity be applied, the skin is destroyed. It also whitens the tongue, thickens the saliva, and produces a flavour on the palate something similar to that of emetin. Its action on oxide of silver is most violent: a drop of the oxygenated water let fall on the dry oxide, occasions an explosion, with evolution of heat and light. Many other oxides, beside that of silver, act also with great energy on oxygenated water, as the peroxides of manganese and cobalt, and the oxides of lead, platina, palladium, gold, iridium, &c. Several metals, when minutely divided, produce similar phenomena, as silver, platina, gold, osmium, iridium, rhodium, and palladium. In the preceding instances, the oxygen combined with the water flies off, and sometimes that of the oxide also; but some of the other metals unite with the oxygen disengaged at the moment the compound is decomposed, and are converted into acids; such are arsenic, molybdena, and tungsten; and also the new substance, selenium. These phenomena are often attended with the evolution of light.

The acids render the combination of the oxygen and water more stable. Thus gold, very finely divided, acts with great energy on *pure* oxygenated water, but has no action on water containing a little sulphuric acid (*a*).

(*a*) The desultory manner in which M. Thenard's experiments were from time to time communicated to the world, must be my apology for presenting them in the same unconnected state, in this volume, which was too far advanced in its progress through the press, when the final results were announced, to allow me to reduce the whole (as I should otherwise have done) into a more condensed and regular form.

M. *Separation of Sulphur and Arsenic.*

Mr. Richard Phillips has lately given us a method of separating these two substances. It consists in boiling them with nitric acid, saturating the sulphuric and arsenic acids thus formed, with potassa, and then pouring in a solution of nitrate of barya. Sulphate of barya falls down, but the arseniate remains in solution. The sulphate being separated by the filter, nitrate of lead is to be added to the clear liquor, as long as any arseniate of lead is precipitated. From the quantities of sulphate of barya, and arseniate of lead, those of the sulphur and arsenic are ascertained. 100 parts of sulphate of barya are equivalent to 13.6 parts of sulphur, and 100 of arseniate of lead to 22.35 of arsenic. Simple as this method is, the communication is valuable, because, as Mr. Phillips observes, "the arseniate of barytes is described as an insoluble salt," in many chemical works. Thus, Thomson, System of Chemistry, vol. ii. page 477. "This salt is insoluble in water, except there be an excess of acid." Mr. Phillips however found that on pouring a solution of arseniate of potassa into one of nitrate of barya, no immediate precipitation occurred, though after standing some days, very delicate feathery crystals of arseniate of barya, were formed.—(Quarterly Journal of Science and the Arts, vol. x. page 100.)

N. *Test for Iodine.*

"Lampadius has observed, that Iodine dissolves with great facility in sulphuret of carbon, and gives it a dark brownish colour. One grain of iodine gives a deep colour to 1000 grains of this liquid. Hence he recommends the sulphuret of carbon, as an excellent re-agent, for detecting the presence of iodine."—(Annals of Philosophy, vol. xiii. p. 310.)

O. *Boracic Acid in Hard Stones.*

In note *a*, p. 186, it is stated that "hitherto only the fluoric and phosphoric acids have been found in the hard stones employed as gems." Since that page was printed off, an analysis of green Tourmaline, by M. Arfwedson, and another of the Rubelite (tourmaline apyre of Haüy) by M. Berzelius, have been published in the Annales de Chimie, in both of which substances they have found boracic acid (*a*). I shall add a short sketch of the analysis by M. Arfwedson.

A portion of the green tourmaline in fine powder, was strongly heated for an hour, with four times its weight of carbonate of barya; the mass was dissolved in hydrochloric acid, and the solution evaporated to dryness. Water, acidulated with hydrochloric acid, then dissolved every thing but the silica.

The barya was separated from the solution by sulphuric acid, and the other earths, with the oxides of iron and manganese, by an excess of carbonate of ammonia. The solution being separated from the precipitate, and evaporated to dryness, a sulphate was obtained, which when again treated with ammonia as before, dried, and heated red, redissolved

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(*a*) Green tourmaline also contains lithia, and rubelite both lithia and soda.

in water without leaving any residuum. This solution was freed from its sulphuric acid, by acetate of barya, and the filtered liquid evaporated. A gummy mass was obtained, which by calcination in a platina crucible, was decomposed and afforded a fused alkaline mass, which proved to be lithia. "I began to consider my work almost finished," (adds M. Arfwedson) "when on drying and heating a portion of the alkaline solution, I observed, at the moment the mass began to fuse, that it swelled up, like borax, and left a glass, after calcination, of the same appearance as vitrified borax. It was very probable therefore, that the mineral contained boracic acid, and I ascertained it by heating the fused mass with muriatic acid, which gave me, by evaporation, a salt, partly soluble in alcohol, to which it imparted the property of burning with the greenish flame so characteristic of boracic acid."

To obtain the quantity of this acid, a portion of the mineral was fused with supersulphate of potassa, the mass boiled with alcohol and the filtered liquid evaporated to dryness. A substance remained, equal to 1.1 per cent of the weight of the tourmaline, and having all the properties of boracic acid.—(Annales de Chimie, vol. x. page 98.)

P. *Treatment of Stones, containing a large proportion of Alumina.*

"Some minerals which contain little silica, and a great deal of alumina, will not be rendered quite soluble by heating them with an alkali. In such cases a portion of insoluble matter remains, upon which the muriatic acid has no action. This is a portion of the mineral in its original state. To render it soluble we must repeat the heating with an alkali, softening with water, and adding muriatic acid till we obtain a complete solution. Five or six repetitions of these processes may in some cases be requisite. With such minerals it is better to employ litharge or borax, or phosphoric acid, than potash or soda. We will then obtain a complete solution by one process, which will greatly diminish the risk of error."—(Sup. Ency. Brit. vol. iii. p. 519.)

Q. *Analysis of Carbonates.*

Instead of the flask and spiral tube, mentioned at page 209, a Woulfe's bottle, with two necks, may be used, as recommended by Dr. Thomson.

"To one of the mouths let a crystal stopper be fitted; the other must remain open. Pour into this phial a quantity of concentrated nitric acid, recently heated to deprive it of the nitrous gas which the smoking acid of the shops always contains. Put into the mouth of the phial a plug of cotton wool. Balance this phial accurately upon the scales of a good beam. Suppose the carbonate to be subjected to analysis to be calcareous spar or common limestone. Break the mineral into small pieces, of such a size that they can conveniently pass through the mouth of the phial. But let there be no powder. Into the same scale that contains the phial with the nitric acid, put fifty grains of these pieces, and counterpoise them exactly by fifty grains weight put into the opposite scale. The nitric acid must have been poured into the phial through the mouth furnished with a glass stopper. As soon as it is poured in, the mouth must be wiped with a piece of paper, and the stopper put in its place. Remove the cotton plug, and with a pair of forceps lift up the pieces of calcareous spar, and put them one after another into the phial through the open mouth. Then replace the cotton plug; the pieces will immediately begin to dissolve with effervescence, owing to the escape of the carbonic acid gas, and in proportion to its escape the weight will diminish, and the opposite scale will preponderate. When the solution is completed, or when the effervescence is at an end, remove the phial from the balance; place it upon a table; take out the glass stopper, and the cotton plug, then introduce through one of the mouths of the phial a small glass tube, and plunge it nearly, but not quite so low as the surface of the nitric acid. Apply the mouth to the other end of the tube, and blow air gently through it for about a minute. Then draw in air through it into the mouth for about another minute. This will remove the carbonic acid gas which is usually floating in the empty part of the phial, and materially affects the weight. Put the glass stopper and the cotton plug again in their places. Put the phial on the same scale of the balance where it was before, and add weights till the equilibrium is restored. These weights are equivalent to the weight of the carbonic acid which had made its escape during the solution of the mineral in the nitric acid."—(Sup. Ency. Brit. vol. iii, p. 521.)

B. *Oxides, which in a gelatinous state, are very soluble in solutions of Potassa or Soda, especially when heated.*

Silica.
Alumina.
Glucina.
Oxide of zinc.
The oxides of tin, especially the deutoxide.
Arsenious acid.
Antimonious and antimonic acids.
Oxide of tellurium.
Oxide of lead.

Oxides, less soluble in the same solutions.

The oxides of manganese, chiefly the deutoxide and peroxide.
Oxide of antimony.
Hydrated oxide of nickel.
Hydrated oxide and deutoxide of iron.
Oxide of rhodium.

Lime, barya, and strontia, especially the two latter, also dissolve some oxides, but only in small quantities. Those on which they appear to have most action, are the oxides of zinc and lead. According to M. Vauquelin, alumina is also slightly soluble in barya and strontia.

The mutual action of the oxides on each other, sometimes occasions their precipitation from water, and even from solutions in alkaline and acid menstrua.

1. If water of barya be added to a solution of silicated potassa, the silica and barya fall down in combination. Strontia and lime water, produce the same effect.

2. Mix a concentrated solution of silicated potassa, with another of alumina and potassa, an opake gelatinous precipitate of silica and alumina, intimately combined, almost immediately ensues.
3. If lime water and alumina, in a gelatinous state, be agitated together, the lime will combine with the alumina, and when separated by the filter, the water will be left pure. According to Chenevix, alumina assists the solution of lime in potassa and soda.
4. When ammonia is poured into an acid solution of sulphate of magnesia, a soluble ammoniaco-magnesian sulphate is formed, indecomposable by ammonia; but if an acid solution of sulphate of alumina, be previously added, the alumina, if in sufficient quantity, carries down with it, at the moment of its precipitation, all the magnesia of the magnesian salt, and only sulphate of ammonia is left in the filtered liquor. The same thing happens if we employ a solution of the bicarbonate of potassa, which does not precipitate the magnesia from its sulphate if the salt be pure, but throws it down entirely, if mixed with a sufficient quantity of sulphate of alumina.
5. Water precipitates oxide of antimony from its chloride, which it decomposes. Chloride of tin, is very soluble in water; but if two parts of chloride of tin, be mixed with one of chloride of antimony, and a large quantity of water be added, the precipitated oxide of antimony will carry the oxide of tin down with it. (Thenard, vol. ii. p. 200.)

I have inserted this extract (although the subject has not been overlooked in some of the preceding pages), in order to warn the student of the action of different substances on each other, when in solution together. Ignorance of these facts, or inattention to them, is likely to produce serious errors in the results of an analysis.

Further observations on the Alkali from the Bean of St. Ignatius, and Nux Vomica, (Strychnus Nux Vomica, and Strychnus Ignatia,) by M. M. Pelletier and Caventou. (Annales de Chimie, vol. 10. page 142.)

In deference to the opinion of some of the Members of the French Academy of Sciences, the authors propose to change the name of this substance, which they at first called *Vauqueline*, (see § 237) to *Strychnine*, since "a name dearly loved, ought not to be applied to a noxious principle."

To obtain strychnine, the bean of St. Ignatius was grated, and heated with sulphuric ether, in a close vessel, under pressure, which dissolved an oily matter; the residuum then yielded a yellowish brown very bitter substance, by the action of alcohol, which being boiled with pure magnesia, and filtered, the colouring matter was washed out, and the *strychnine* and magnesia, in a state of mixture, remained on the filter. The strychnine was then separated by alcohol, from the magnesia, and thus obtained in a state of great purity.

It is highly alkaline, crystallizes in very small four-sided prisms, terminated by four-sided pyramids; if rapidly crystallized, it is white and granular. Its taste is insupportably bitter, and leaves a sort of metallic flavour on the palate; it has no smell; its action on animals is extremely violent, occasioning convulsions and death. It is not altered by exposure to the air; it is decomposed by a heat not exceeding 600°, but is neither fusible nor volatile. Notwithstanding its strong taste, it is very little soluble in water, requiring 6667 parts of that fluid for its solution at 50°, and 2500 at 212°. It is very soluble in alcohol; it forms neutral and crystallizable salts, with acids.

Neutral sulphate of strychnine crystallizes in cubes. This, as well as all the other salts, is intensely bitter, and is decomposed by all the soluble salifiable bases, which precipitate the strychnine. A little concentrated nitric acid, poured on sulphate of strychnine, turns it blood-red; a further quantity changes the colour to yellow. This property also is common to all the salts of strychnine as well as to their base. The sulphate is not altered by exposure to the air; it fuses at a heat a little above 212°, but soon solidifies again, losing $\frac{3}{100}$dths of its weight; at a higher heat it is decomposed.

It is composed of	sulphuric acid .	9.5.
	strychnine . . .	90.5
		100.0

And its equivalent number is 357.

The hydrochlorate of strychnine crystallizes in very delicate quadrangular prisms grouped together in mammellæ: the phosphate, in very distinct quadrangular prisms.

The neutral nitrate (which can only be formed by adding an excess of strychnine to the acid very much diluted) crystallizes in small pearly needles, grouped together; at a heat a little above 212° they become yellow, and are decomposed. Nitrate of strychnine is sparingly soluble in alcohol, and insoluble in ether.

The property of strychnine, and its salts, to become red by the action of concentrated nitric acid, affords a test to distinguish that acid or the nitrates. To a salt supposed to contain a nitrate, add a little strychnine, and a few drops of sulphuric acid. The presence of the nitrate will be detected by the red colour which the mixture will assume.

Nitric acid, by long boiling with strychnine, gradually weakens its alkaline, bitter, and poisonous properties, and at last totally destroys them; and it is probable that with the necessary precautions it might be made to undergo a series of modifications, tending to produce, first a substance having diminished alkaline properties, then a neutral substance, and lastly an acid, for some oxalic acid appeared to be formed by the long continued action of nitric acid on strychnine.

Sulphuretted hydrogen destroys the colour of the red compound of strychnine, as does the hydrochlorate of protoxide of tin, protosulphate of iron, and sulphurous acid gas.

Subcarbonate of strychnine is little soluble in water, but very soluble in carbonic acid; the carbonate loses its excess of acid, by exposure to the air, and the subcarbonate separates in granular crystals.

Sulphur and carbon do not combine with strychnine: iodine, and chlorine, form crystallizable salts with it.

Strychnine, dissolved in alcohol, precipitates their oxides from solutions of the metallic salts, and the same effect is produced, by boiling it in metallic solutions; the strychnine dissolves, and the oxide falls down. In some cases, as with oxide of copper, it forms double salts.

Except the vegetable acids, with which it forms very soluble neutral salts, strychnine has little action on vegetable substances, as sugar, starch, gum, &c.; it does not unite with the fixed oils, but it is very soluble in the essential oils.

The acid with which strychnine is combined in the bean of St. Ignatius, has some analogy with the malic; evaporated to a syrup it forms hard granular crystals; it is very soluble in water and in alcohol; its taste is acid and very styptic; the salts it forms with earthy and alkaline bases, are soluble in water. It gives no precipitate with salts of silver, mercury, or iron, but decomposes the salts of copper, which it changes to a green colour, and a greenish white salt, very sparingly soluble in water, is gradually deposited. Supposing it probable that the acid of the strychnine (for it exists in all the tribe) is a new substance, M. M. Pelletier and Caventou propose to call it the *Igasuric* acid, from the Malay name for the bean of St. Ignatius. The strychnine therefore exists in the bean, as an *igasurate*.

Hyposulphurous and Hyposulphuric Acids.

"Besides the two acid compounds of sulphur and oxygen, (viz. sulphurous and sulphuric acids) we have the fullest evidence of the existence of a third, composed of 1 atom sulphur + 1 atom oxygen, or of 100 sulphur + 50 oxygen, by weight, and to which the name of *hyposulphurous* acid may be given. This acid has not been hitherto obtained in a separate state, but it can be obtained readily enough united to bases (*a*) constituting the salts at present known by the name of *sulphuretted sulphites*."—(Thomson's Chemistry, vol. ii. p. 112. 5th edition.)

It was M. Gay Lussac who first conceived these salts to contain a peculiar acid, which he proposed to call the persulphurous, but afterwards changed the name to that of hyposulphurous acid. As it has never been obtained in a separate state, I have not included it amongst the acids, in the former part of this work. M. Gay Lussac, however, has very recently announced the existence of a fourth acid compound of sulphur and oxygen, which he has obtained in an insulated form, or, at least, only combined with water.

There seems no reason to question the peculiar nature of this latter acid, since the properties of the salts it forms with certain bases, are decidedly different from those of the sulphates or sulphites of the same bases, to say nothing of the little probability, that so eminent a chemist as M. Gay Lussac, should

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(*a*) By passing a current of sulphuretted hydrogen into a solution of the sulphite.

err in such a point. I therefore subjoin an abstract of its properties, from the paper which appeared in March last in the Annales de Chimie, vol. x. p. 312.

I may add, that the discovery of this acid very much strengthens the argument in favour of the existence of the hyposulphurous, although Dr. Thomson is of opinion that "in chemistry analogies are always dangerous, and generally mislead."—System of Chemistry, vol. ii. p. 684. 5th edition.

On a new Acid, formed by Sulphur and Oxygen.

By M. M. Welter and Gay Lussac.

The authors propose to name this new acid, the *hyposulphuric*, by analogy with the *hyposulphurous*, to denote that it contains less oxygen than sulphuric acid, and more than sulphurous acid. Its salts of course must be denominated *hyposulphates*. Hyposulphuric acid is obtained by passing sulphurous acid gas into water holding peroxide of manganese in suspension. Neutral sulphate, and hyposulphate of manganese are formed. Barya water is then to be added in excess, which will decompose the salts of manganese, the sulphate of barya falling down, whilst the hyposulphate remains in solution. The excess of barya is next to be separated by a current of carbonic acid gas, and the solution heated to expel the surplus carbonic acid. It now contains only hyposulphate of barya, (with perhaps a small portion of calcareous salt, since the ores of manganese are seldom quite free from lime) and the salt may be obtained perfectly pure by evaporating and crystallizing. This done, redissolve the hyposulphate, and add, very cautiously, sulphuric acid, to the exact point of saturation, by which means the salt will be decomposed, and its acid obtained free.

Hyposulphuric acid is inodorous, even in its most concentrated state. Its flavour is decidedly acid. It does not appear to be capable of existing in the gaseous form: exposed to a vacuum with sulphuric acid at the temperature of 50° it is concentrated, without being perceptibly volatilized. When its density amounts to 1.347 it begins to decompose, sulphurous acid exhales from it, and it then contains sulphuric acid.

Heat at first expels only pure water from the diluted acid, but sulphurous acid also soon begins to rise, and sulphuric acid to be formed. The heat of boiling water is sufficient to produce this decomposition. Chlorine, strong nitric acid, and the red sulphate of manganese, produce no change on it whilst cold. It forms neutral soluble salts with barya, strontia, lime, oxide of lead, and probably with all the other bases. It dissolves zinc, and the solution is attended with the evolution of hydrogen, but the acid is not decomposed. M. M. Gay Lussac and Welter, could not obtain hyposulphuric acid, by acting on the peroxides of baryum or lead by sulphurous acid, although their composition is analogous to that of the peroxide of manganese.

The hyposulphates are very permanent at low temperatures, but are decomposed by a moderate heat, and sulphurous and sulphuric acids are produced. They are not altered by cold diluted sulphuric acid, but if the mixture be heated, or the acid concentrated, sulphurous acid is immediately disengaged. Solutions of the hyposulphates are not altered by exposure to the air, at least the change is effected very slowly.

Hyposulphate of barya crystallizes in brilliant quadrangular prisms terminated by a great number of facettes; it is soluble in about seven or eight parts of water at 47°. Chlorine effects no change in the solution. The salt decrepitates strongly, and is decomposed by a moderate heat.

The form of the crystal of hyposulphate of potassa, is a cylindrical (*cylindroide*) prism, terminated by a plane, perpendicular to its axis.

Hyposulphate of lime crystallizes in regular hexagonal plates.

The crystals of hyposulphate of strontia are very small. Their form appears to be that of hexaedral plates, whose alternate edges are inclined in contrary directions, as would result from the section of an octohedron, parallel to two of its opposite faces.

The analysis of hyposulphuric acid was effected by means of the hyposulphate of barya. 100 parts of this salt, well dried, lost by calcination 29.903 parts, and 70.097 of sulphate of barya were left. Other 100 parts of the same salt, being mixed with chlorate and carbonate of potassa, and heated red in a platina crucible, gave by precipitation with chloride of barium, 138.3 of sulphate of barya.

These numbers are nearly as 1:2; the difference not being greater than may be ascribed to unavoidable loss in the washings, &c.

The equivalent for	sulphuric acid is . . .	37.5
	sulphurous acid . . .	30.
	barya	72.75
		140.25

Supposing a compound constituted as above, to part with its sulphurous acid by calcination, 100 parts would lose 21.32, but 100 of the salt lost 29.903; they contain therefore 8.6 parts of water. An atom of water weighs 8.5; if we conceive the hyposulphate of barya to contain two proportions of water, its equivalent number will be (140.25 + 17) 157.25, and supposing it to lose 47 in water and sulphurous acid by calcination, 100 parts would lose 29.89, and consequently leave 70.11 of sulphate of barya, instead of 70.097.

The composition of the salt may therefore be stated as follows:

1 atom	of barya	72.75
1	of sulphuric acid . . .	37.5
1	of sulphurous acid . .	30.
2	of water	17.
		157.25

Or	1 atom	of barya	72.75
	1	of hyposulphuric acid . .	67.5
	2	of water	17.
			157.25

And the composition of hyposulphuric acid must be,

2 atoms of sulphur	30.
5 of oxygen	37.5
And its equivalent number . .	67.5

Thus, adds M. Gay Lussac, we have an acid whose salts remain in the state of neutral sulphates, by losing one proportion of sulphurous acid; it contains the same proportionate quantity of sulphur as hyposulphurous acid, and twice and a half as much oxygen. These two acids must be considered as forming a separate groupe amongst the acids of sulphur; sulphurous and sulphuric acids will form the other. This distinction is necessary, since the quantity of sulphur in each of these groupes is different, and their composition cannot be expressed by the terms of the same series. The salts of each groupe have also much greater relation to one another, than they have to those of the other groupe.

Collecting in one view, the different acids formed by sulphur and oxygen, their composition is as follows:

Hyposulphurous acid contains	2 atoms of sulphur	+ 2 of oxygen
Hyposulphuric - -	2 - - -	+ 5
Sulphurous - -	1 - - -	+ 2
Sulphuric - -	1 - - -	+ 3

Or taking the sulphur as the constant quantity, the oxygen combines with it in the following proportions: 1; 2; 2.5; 3. In conclusion, we may state that hyposulphurous acid is distinguished from all the other acids of sulphur:—

1. By being converted into sulphurous and sulphuric acids by heat.
2. By forming *soluble* salts with barya, strontia, lime, lead, and silver.

The characters of the hyposulphates are,

1. They are all soluble.
2. Acids do not disengage sulphurous acid from their solutions, unless the mixture heat spontaneously, or be exposed to heat.
3. They give off sulphurous acid, at high temperatures, and are converted into sulphates.

Hyposulphurous Acid.

Mr. Herschel, in a very elaborate paper on this subject, which appeared in the first number of the Edinburgh Philosophical Journal, for June, 1819, has confirmed M. M. Gay Lussac and Welter's estimate of the composition of this acid, which he proves, both from experiment, and from calculation, to be formed of one atom of sulphur 15 + one of oxygen 7.5 = 22.5; but in combination with bases, forming hyposulphites, two atoms of the acid, are always combined with one of the base; thus hyposulphite of lime consists of

Lime (1 atom) . .	= 26.5
Acid (2 S. + 2 O) .	= 45.
	71.5

Mr. Herschel has not been much more successful than former experimenters in his attempts to obtain the hyposulphurous acid in an insulated state, but he gives a very full description of many of its salts. The hyposulphites are, for the most part, very soluble in water, and the solutions have usually either an intensely bitter, or an intensely sweet taste. They are decomposed at a heat below redness; sulphur separates and a sulphite or sulphuret of the base remains. Chlorine and nitric acid separate sulphur, and convert them into sulphates. They are decomposed by all the acids, except the carbonic, and perhaps one or two of the other less powerful ones. The hyposulphites precipitate lead from its solutions, in the form of a white powder, which is hyposulphite of lead.

Oxynitrate (qu.—*Nitrate?*) of silver, and nitrate of mercury, dropped in excess into a dilute solution of any hyposulphite, give a precipitate of their respective metals in the state of sulphurets.

Nitrate of bismuth, *when heated*, undergoes the same change. The salts of manganese, iron, zinc, copper, and tin, are not precipitated.

Nitrate of mercury is a very delicate test of the presence of hyposulphurous acid. With a solution containing $\frac{1}{10000}$dth of its weight of the acid, it immediately strikes a deep brown, and when only $\frac{1}{100000}$dth is present, it opalesces on a few minutes standing.

The decomposition of nitrate of silver by hyposulphite of lime, is thus explained by Mr. Herschel. Hyposulphite of lime contains (as stated above) 1 atom of lime + 1 atom of hyposulphurous acid, or 2 sulphur + 2 oxygen. Nitrate of silver contains 1 atom nitric acid + 1 atom of oxide of silver, or 1 silver + 1 oxygen. On mixing the solutions, the atom of nitric acid combines with the atom of lime, and forms an atom of nitrate of lime. One atom of sulphur combines with the atom of silver, to form sulphuret of silver, and the other atom of sulphur unites with the three atoms of oxygen, (namely, two from the hyposulphurous acid, and one from the oxide of silver), and forms one atom of free sulphuric acid, whose presence is manifest by the formation of sulphate of barya, on adding a barytic salt.

One of the most singular characters of the hyposulphites, is the property their solutions possess, of dissolving recently precipitated chloride of silver. Hyposulphite of soda, dissolves it with great facility, and in large quantity. The solution is accompanied by a "sweetness, surpassing even that of honey, and diffusing itself over the whole mouth and fauces, without any disagreeable or metallic flavour." The solution is at first colourless, but by standing becomes coloured, and deposits a brown sediment, which takes place more slowly, or not at all, if the solution be very dilute. It is not precipitated by ammonia, nor its carbonate, nor by the carbonate or prussiate of potassa; but pure potassa occasions a copious precipitate of small pearly scales, similar to boracic acid, of a grey colour, which are hyposulphite of silver and potassa. Hydrochloric acid at first gives no precipitate with the solution, (unless in very copious excess), but on long standing, chloride of silver falls down. The neutral hydrochlorates produce no effect. Alcohol precipitates it in an intensely sweet syrup. Zinc throws down the silver in a metallic state. Chloride of lead is also soluble in solutions of the hyposulphites, but less abundantly than chloride of silver. According to Mr. Herschel, the hyposulphites are best formed, by passing a current of sulphurous acid gas into solutions of the respective hydrosulphurets.

The hyposulphites of barya, lead, and silver, are salts of little solubility.

"When hyposulphite of barya is heated on a platina foil, it is thrown into a singular agitation, and seems enveloped in a kind of fog, caused by its own dust, thrown up in an infinite number of minute explosions. It takes fire at a very low heat, and sulphur burns off."

In order to form hyposulphite of alumina, Mr. Herschel mixed oxalate of alumina with hyposulphite of lime, but to his surprise, though both the solutions were perfectly neutral, not the slightest cloud was produced. The same phenomenon takes place with the hydrochlorate and nitrate of lime.

"A singular suspension of one of the strongest chemical affinities."

(Edinburgh Philosophical Journal, June, 1819.)

Each of the three following Tables is divided into five heads, and every head into three columns. The first head contains the uncompounded substances, the second oxygen, the third chlorine, the fourth iodine, and the fifth sulphur; except in the first table, where the fifth head is devoted to hydrogen. The first column of the first head gives the proportional number or weight of an atom of the simple substance which stands opposite to it in the second column. The third column contains the number of atoms of the same substance, which combining with one or more atoms of the substance contained in one of the other four heads, forms the compound named in the middle column of that head, the number in the preceding column denoting the number of atoms combining with the simple substance, and that in the column immediately following it, the weight of the compound atom. Thus, 1 atom of baryum + 1 atom of oxygen, forms one atom of barya, the weight of whose atom is (65 + 7.5) 72.5. and 1 atom of baryum + 1 of chlorine, forms chloride of baryum = 98.5. 1 of baryum + 1 of iodine = 1 of iodide of baryum = 182.75, and 1 of baryum + 1 of sulphur forms 1 of sulphuret of baryum whose atom weighs 80.

When no compound is named in the column immediately following the number of combining atoms, the eye must be carried along in the same line to the succeeding columns, in one of which, another number, denoting some other combining atom or atoms will be found, and opposite to it, the name of the substance formed (which in this case must have three elements) and its number. Thus, 1 atom of baryum + 6 atoms of oxygen + 1 atom of chlorine, forms chlorate of barya = 143.5. And again, 1 of baryum + 4 of oxygen, + 1 of sulphur, forms sulphate of barya = 110. That is, in the first instance, 1 atom of barya = 72.5 unites with 1 of chloric acid, = 71, and in the second 1 of barya 72.5 combines with one of sulphuric acid = 37.5.

By referring to the composition of the oxide, and of the acid, (which will be found in the first table) the nature of any triple combination will easily be inferred.

A quantity of any acid, equal to the weight of its atom, plus a quantity of base, containing 7.5 of oxygen, forms a neutral salt. For neutral ammoniacal salts, instead of a base containing 7.5 oxygen, take 16.15 ammonia.

Simple Substances.			Oxygen, 7.5.			emarks.
Weight of an atom.		No. of atoms combining.	No. of atoms combining.	Compound formed.	Weight of compound atom.	
7.5	Oxygen -	- -	- -	- - -	- -	
33.5	Chlorine	1	1	Oxide of Chlorine	41.	
		1	4	Deut. ox. Chlor.	63.5	
		1	5	Chloric acid - -	71.	
		1	7	Perchloric acid	86	
		1	- -	- - -	- -	
117.75	Iodine - -	1	5	Iodic acid - -	155.25	
1.	Hydrogen -	1	1	Water - - - -	8.5	
		1	2	Deutox. of Hydro.	16.	
13.15	Azote - -	1	1	Oxide of Azote -	20.65	
		1	2	Deutoxide of Azote	28.15	
		1	3	Pernitrous Acid -	35.65	
		1	4	Nitrous Acid -	43.15	
		1	5	Nitric Acid - -	50.65	27 (= 2 water)
		1	- -	- - -	- -	uid nitric acid.
15.	Sulphur -	1	2	Sulphurous Acid	30.	
		1	3	Sulphuric Acid -	37.5	
		2	2	Hyposulphurous A.	45	5 (= 1 water) =
		2	5	Hyposulphuric A.	67.5	lphuric acid.
11.5	Phosphorus	2	1	Oxide of Phosphor	30.5	
		1	1	Phosphorous Acid	19.	orous acid = 38 l water) = hy-
		1	2	Phosphoric Acid	26.5	rousacid = 46.5. orous + 1 sul- phuret of phos- 38.
5.7	Carbon -	1	1	Oxide of Carbon	13.2	+ 1 azote =
		1	2	Carbonic Acid -	20.7	24.4. n + 1 chlorine
		2	- -	- - -	- -	nic acid = 57.9. n + 1 hydrogen
		3	3	- - -	- -	nic acid = 25.4. + 2 sulphur =
		1	1	- - -	- -	carbon = 35.7.
5.	Boron - -	1	2	Boracic Acid -	20.	= 2 water) =
37.43	Selenium - -	1	2	Selenic acid - -	52.43	c acid = 37. nium + 1 hy-
15.	Silicium - -	1	2	Silica - - - -	30.	.43 selenuretted
16.5	Aluminium -	1	1	Alumina - - -	24.	
20.	Glucinium -	1	1	Glucina - - -	27.5	
30.	Yttrium - -	1	1	Yttria - - - -	37.5	
11.	Magnesium -	1	1	Magnesia - - -	18.5	esia + 34.5 hy- id = 52 hydro-
34.69	Zirconium -	1	1	Zircona - - -	42.19	agnesia. esia + 37.5 sul- = 56 sulphate
	Thorinium -					
37.5	Potassium -	1	1	Potassa - - -	45.	
		1	3	Peroxide of Potassium - -	60.	(= 1 water) = of potassa.
		1	6	- - -	- -	sa + 34.5 hy- acid = 79.5 hy- e of potassa.
		1	8	- - -	- -	
		1	6	- - -	- -	+ 118.75 hy- = 163.75 hy- otassa,

Simple Substances.			Oxygen, 7.5.				rks.
Weight of an atom.		No. of atoms combining.	No. of atoms combining.	Compound formed.	Weight of compound atom.	No. of atoms combining	
37.5	Potassium -	1	3				
				- - -	- -	- -	
		1	4	- - -	- -	- -	
22.	Sodium - -	1	1	Soda - - - -	29.5	1	
		1	6	- - -	- -	1	34.5 hydro- : 64 hydro- a.
		1	6	- - -	- -	- -	118.75 hy- : 148.25 hy- i.
		1	4	- - -	- -	- -	
10.31	Lithium - -	1	1	Lithia - - - -	17.81	1	(= 1 water) te of lithia.
		1	6	- - -	- -	1	34.5 hydro- 52.31 hydro- ia.
		1	6	- - -	- -	- -	+118.75 hy- : 136.56 hy- ia.
		1	4	- - -	- -	- -	
65.	Baryum - -	1	1	Barya - - -	72.5	1	= hydrate of
		1	2	Perox. of Baryum	80.		
		1	6	- - -	- -	1	= 107 hydro- ya.
		1	6	- - -	- -	- -	75 = 191.25 arya.
		1	4	- - -	- -	- -	
44.5	Strontium -	1	1	Strontia - - -	52.	1	60.5 hydrate
		1	6	- - -	- -	1	: 86.5 hydro- ntia.
		1	6	- - -	- -	- -	5 = 170.75 :rontia.
		1	4	- - -	- -	- -	
19.	Calcium - -	1	1	Lime - - - -	26.5	1	= 35 hydrate
		1	6	- - -	- -	1	= 61 hydro- :.
		1	6	- - -	- -	- -	75 = 145.25 me.
		1	4	- - -	- -	- -	
53.5	Manganese -	1	1	Ox. of Manganese	61.	1	1 water) = of oxide of
		1	2	Deutox. of Manga.	68.5		
		1	4	Peroxide - - -	83.5	- -	95.5 hydro- ganese.
		1	4	- - -	- -	- -	
33.	Zinc - -	1	1	Oxide of Zinc -	40.5	1	=75.0 hydro- :.
		1	4	- - -	- -	- -	
52.	Iron - - -	1	2	Oxide of Iron -	67.	2	136 hydro- l.
		1	3	Peroxide of Iron -	74.5	3	5 = 178 hy- peroxide of
		1	8	- - -	- -	- -	
		1	12	- - -	- -	- -	
55.	Tin - - -	1	1	Oxide of Tin -	62.5	1	= 97 hydro-
		1	2	Peroxide of Tin -	70.	2	: 139 hydro- oxide of tin.

Simple Substances.			Oxygen, 7.5.			rks.	
Weight of an atom.		No. of atoms combining.	No. of atoms combining.	Compound formed.	Weight of compound atom.	No. of atoms combining	
37.5	Potassium -	1	3				
				- - -	- -	- -	
		1	4	- - -	- -	- -	
22.	Sodium - -	1	1	Soda - - - -	29.5	1	
		1	6	- - -	- -	1	34.5 hydro- : 64 hydro- a.
		1	6	- - -	- -	- -	118.75 hy- : 148.25 hy- i.
		1	4	- - -	- -	- -	
10.31	Lithium - -	1	1	Lithia - - - -	17,81	1	(= 1 water) te of lithia.
		1	6	- - -	- -	1	34.5 hydro- 52.31 hydro- ia.
		1	6	- - -	- -	- -	118.75 hy- : 136.56 hy- ia.
		1	4	- - -	- -	- -	
65.	Baryum - -	1	1	Barya - - -	72.5	1	= hydrate of
		1	2	Perox. of Baryum	80.		
		1	6	- - -	- -	1	= 107 hydro- ra.
		1	6	- - -	- -	- -	75 = 191.25 arya.
		1	4	- - -	- -	- -	
44.5	Strontium -	1	1	Strontia - - -	52.	1	60.5 hydrate
		1	6	- - -	- -	1	86.5 hydro- ntia.
		1	6	- - -	- -	- -	5 = 170.75 trontia.
		1	4	- - -	- -	- -	
19.	Calcium - -	1	1	Lime - - - -	26.5	1	; 35 hydrate
		1	6	- - -	- -	1	= 61 hydro-
		1	6	- - -	- -	- -	75 = 145.25 me.
		1	4	- - -	- -	- -	
53.5	Manganese -	1	1	Ox. of Manganese	61.	1	1 water) = of oxide of
		1	2	Deutox. of Manga.	68.5		
		1	4	Peroxide - - -	83.5	- -	95.5 hydro- nganese.
		1	4	- - -	- -	- -	
33.	Zinc - -	1	1	Oxide of Zinc -	40.5	1	= 75.0 hydro-
		1	4	- - -	- -	- -	
52.	Iron - - -	1	2	Oxide of Iron -	67.	2	136 hydro-
		1	3	Peroxide of Iron -	74.5	3	5 = 178 hy- peroxide of
		1	8	- - -	- -	- -	
		1	12	- - -	- -	- -	
55.	Tin - - -	1	1	Oxide of Tin -	62.5	1	= 97 hydro-
		1	2	Peroxide of Tin -	70.	2	: 139 hydro- oxide of tin.

Simple Substances.			Oxygen, 7.5.				
Weight of an atom.		No. of atoms combining.	No. of atoms combining.	Compound formed.	Weight of compound atom.	No. of atoms combining.	
44.	Arsenic - -	1	2	Arsenious Acid -	59.	2	
		1	3	Arsenic Acid -	67.5	- -	
44.	Molybdena -	1	1	Oxi. of Molybdena	51.5		
		1	2	Deutox. of Molyb.	59.	- -	
		1	3	Molybdic Acid -	66.5		
28.5	Chromium -	1	1	Oxide of Chromium	36.		
		1	2	Chromic Acid -	43.5		
90.	Tungsten -	1	2	Brown Oxide of Tungsten - -	105.		
		1	3	Tungstic Acid -	112.5		
139.	Columbium -	1	1	Oxide of Columbi.	146.5		
45.	Antimony -	1	1	Antimonious Acid	52.5	1	
		1	2	Antimonic Acid -	60.		
60.	Uranium -	1	1	Oxide of Uranium	67.5		
		1	2	Peroxide of Uran.	75.		
86.2	Cerium -	1	2	Oxide of Cerium -	101.2		
		1	2	Peroxide of Cerium	108.5		
43.	Cobalt - -	1	1	Oxide of Cobalt -	50.5	1	
		1	2	Peroxide of Cobalt	58.		
135.	Titanium -	1	1	Oxide of Titanium	142.5		
66.5	Bismuth - -	1	1	Oxide of Bismuth	74.	1	
60.	Copper - -	1	1	Oxide of Copper	67.5	1	peroxide) m hydro- 84.5 sub- eroxide of
		1	2	Peroxide of Copper	75.	2	atoms hy- = 144 hy- roxide of
		1	8	- - -	- -	- -	
37.	Tellurium -	1	1	Oxide of Tellurium	44.5	1	
82.5	Cadmium -	1	1	Oxide of Cadmium	90.	1	
28.	Nickel - -	1	1	Oxide of Nickel -	35.5		
		1	4	- - -	- -	- -	
97.	Lead - - -	1	1	Oxide of Lead -	104.5	1	
		2	3	Deutoxide of Lead	216.5		
		1	2	Peroxide of Lead	112.		
		1	4	- - -	- -	- -	
190.	Mercury -	1	1	Oxide of Mercury	197.5	1	
		1	2	Peroxide of Mer.	205.	2	
		1	4	- - -	- -	- -	
	Osmium - -						
102.5	Silver - -	1	1	Oxide of Silver -	110.	1	
		1	4	- - -	- -	- -	
52.5	Palladium -	1	1	Oxide of Palladium	60?		
112.5	Rhodium -	1	1	Oxide of Rhodium	120?		
		1	2	Deutoxide of Rho.	127.5?		
		1	3	Peroxide of Rhod.	135?		
92.	Platina - -	1	1	Oxide of Platina -	99.5	1	= 134 hy- tina.
97.	Gold - - -	1	1	Oxide of Gold -	104.5?	1	
45?	Iridium - -	- -	- -	- - -	- -	- -	

I copy the following Tables of the Composition of
a work

TABULAR VIE

One 1

	WATERS.	Gases.			Carb	
		Azote C. I.	Carbonic Acid C.I.	Sulphuretted Hydrogen, C. I.	Carbonate of Soda, grains.	Ca nat Ma
Carbonated.	Seltzer	- -	17,	- -	4,	
	Pyrmont	- -	26,	- -	- -	
	Spa	- -	13,	- -	1,5	
	Carlsbad	- -	5,	- -	5,	
	Pouges	- -	30,	- -	10,	
	Saint Parize	- -	22,	- -	- -	
Sulphureous.	Harrogate	0,8	1,	2,3	- -	
	Moffat	0,5	0,6	1,2	- -	
	Aix la Chapelle	- -	- -	5,5	12,	
	Cheltenham Sulphur Spring	- -	1,5	2,5	- -	
Saline.	Seidlitz	- -	- -	- -	- -	
	Cheltenham pure Saline	- -	- -	- -	- -	
	Bristol	- -	3,5	- -	- -	
	Buxton	0,2	- -	- -	- -	
	Bath	- -	1,2	- -	- -	
	Scarborough	- -	- -	- -	- -	
	Barege	- -	- -	uncertain	2,5	
	Plombieres	- -	- -	- -	2,2	
	Kilburn	- -	3,5	8,5?	- -	
	Lemington New Bath	0,4	A trace	A trace	- -	
	Lemington Old Bath	0,3	- -	ditto	- -	
Chalybeate.	Tunbridge	0.59	1,	A trace of oxygen.	- -	
	Cheltenham Chalybeate	- -	2,5	- -	0,5	
	Brighton	- -	2,2	- -	- -	

TABLE OF THE ATOMIC CONSTITUTION OF CERTAIN VEGETABLE AND ANIMAL SUBSTANCES.

		Weight of elements, per cent.				No. and weight of atoms.				
Substance.	Weight of atom.	Oxygen.	Carbon.	Hydrogen.	Azote.	Oxygen.	Carbon.	Hydrogen.	Azote.	Authority.
Acetic Acid	48.35	46.82	46.83	6.35	....	3=22.5	4=22.8	3=3	....	Berzelius.
Benzoic Acid	111.	20.43	74.41	5.16	....	3=22.5	14=79.8	6=6	....	D°
Succinic Acid	47.	47.8	47.6	4.5	....	3=22.5	4=22.8	2=2	.....	D°
Tartaric Acid	63.	59.9	36.	4.	....	5=37.5	4=22.8	3=3	.....	D°
Citric Acid	55.3	54.8	41.4	3.8	....	4=30.	4=22.8	3=3	....	D°
Saclactic Acid	98.4	61.46	33.43	5.1	....	8=60.	6=34.2	5=5	.....	D°
Formic Acid	35.22	64.76	32.4	2.84	....	3=22.5	2=11.4	1=1	.....	D°
Gallic Acid	60.	38.36	56.64	5.	....	3=22.5	6=34.2	3=3	......	D°
Uric Acid	....	28.85	34.28	2.85	40.	....	....	.....	.....	Dr. Prout.
Tannin	201.75	44.65	51.16	4.18	....	12=90.	18=102.6	9=9		Berzelius.
Sugar	75.	50.63	42.47	4.9	....	5=37.5	6=34.2	5=5	.....	Gay Lussac and Thenard
Gum	84.5	51.3	41.9	6.78	....	6=45.	6=34.2	6=6	....	Berzelius.
Starch	135.	49.45	43.43	7.	....	9=67.5	10=57.	10=10		D°
Wax	....	5.54	81.78	12.67	....	....	....	....	....	Gay Lussac and Thenard.
Rosin	....	13.33	75.94	10.7	....	....	....	....	....	D°
Copal	....	10.6	76.81	12.58	....	...	....	....	....	D°
Woody Fibre	....	42.25	52.	5.75	....	....	....	....	....	D°
Gelatin	....	27.2	47.88	7.91	16.99	....	...	....	....	D°
Albumen	....	23.87	52.88	7.54	15.7	....	....	....	....	D°
Fibrin	....	19.63	53.36	7.	19.93	....	....	....	.....	D°
Sugar of Milk	....	53.83	38.82	7.34	....	....	....	....	......	

TABLE

OF THE SPECIFIC GRAVITY OF GASES AND VAPOURS, AND WEIGHT, PER 100 CUBIC INCHES.

Thermometer, 60°.—Barometer, 30 in.

Substances.	Specific Gravity.	Weight of 100 Cub. In.	Remarks.
Atmospheric air	1.000	30.5	
Oxygen	1.106	33.733	
Chlorine	2.4713	75.874	
Hydrogen	0.737	2.25	
Hydruret of Phosphorus	0.8114	24.75	
Bihydruret of Phosphorus	0.8852	27.000	
Arsenuretted Hydrogen	0.5552	16.933	
Telluretted Hydrogen			
Potassuretted Hydrogen			
Selenuretted Hydrogen			
Hydruret of Carbon	0.9816	30.15	
Bihydruret of Carbon	0.5680	17.325	
~~Carbonic~~ Oxide	0.9737	29.7	
Hydruretted Carbonic Oxide	0.993	30.286	
Cyanogen	1.8064	55.095	
Oxide of Chlorine	2.4192	73.7856	
Deutoxide of Chlorine	2.342	71.4375	
Azote	0.9705	29.6	
Oxide of ~~Azote~~	1.5217	46.4118	
Deutoxide of Azote	1.037	31.6285	
Carbonic Acid	1.5233	46.575	
Chlorocarbonic Acid	3.48	107.075	
Sulphurous Acid	2.2131	67.5	
Fluoboric Acid	2.3709	72.312	
Fluosilicic Acid	3.5735	108.992	
Hydrochloric Acid	1.2725	38.8125	
Hydriodic Acid	4.424	133.5937	
Sulphuretted Hydrogen	1.1808	36.	
Ammonia	0.5901	18.	
Vapour of Iodine	8.695	265.197	
Vapour of Carbon	0.4173	12.7276	
Nitrous Acid Vapour	2.1356	65.1358	
Hydrocyanic Acid Vapour	0.9385	28.624	
Chlorocyanic Acid Vapour	2.1373	65.1876	
Steam	0.6235	....	These densities were determined by M. Gay Lussac, by converting a given weight of liquid into vapour over mercury, at the temperature of 212° Faht. and under the barometical pressure of 29.91 inches, and measuring the volume of vapour produced.
Vapour of Sulphuret of Carbon	2.6447	....	
——— of Hydriodic Ether	5.4749	....	
——— of Sulphuric Ether	2.586	....	
——— of Hydrochloric d°	2.219	....	
——— of Absolute Alcohol	1.6133	....	

TABLE OF THE PHYSICAL PROPERTIES OF THE METALS, AND THEIR OXIDES, &c.

Metal.	Colour.	Sp. Gy.	Hardness.	Malleable or brittle.	Tenacity.	Fusibility.	No. and colour of Oxides.	No. and colour of Chlorides.	No. and colour of Iodides.	No. and colour of Sulphurets.	Date of discovery of the Metal.	By whom discovered.	Remarks.
Silicum							1. white.						The Specific Gravities are compared to that of distilled water, at 60°, which is taken as unity. The hardness is estimated according to Kirwan's method. 3 = hardness of chalk 4—Harder than chalk, but yields to the nail. 5—Does not yield to the nail, but easily and without grittiness to the knife 6—Yields more difficultly to the knife. 7—Scarcely yields to the knife.
Zirconium							1. white.						
Aluminium							1. white.						
Yttrium							1. white.						
Glucinium							1. white.						
Magnesium	white.						1. white.	1. white.			1808	Davy.	
Thorinium							1. white.				1815	Berzelius.	
Potassium	white.	0.86507	4	M		136.5° F.	1. white. 2. yellow	1. white.	1. white.	1. grey.	1807	Davy.	
Sodium	white.	0.97223	4	M		194.° F.	1. white. 2. yellow	1. white.	1. white.	1. grey.	1807	Davy.	
Lithium	white.		4?	M?			1. white.	1. white.			1818	Arfwedson	
Baryum	white.						2. grey.	1. white.	1. white.	1. reddish yellow.	1808	Davy.	
Strontium	white.						1. white.	1. white.	1. white.		1808	Davy.	
Calcium	white.						1. white.	1. white.	1. white.	1. greyish brown.	1808	Davy.	
Manganese	grey.	8.013	8	B.		160.° W.	1. green. 2. black.	1. pink.		1. green.	About 1774	Gahn & Scheele.	
Zinc	white.	7.1908	6.5	M	109.8	680.° F.	1. white.	1. white.	1. white.	1. yellow.	About 1540	Paracelsus.	
Iron	grey.	7.8	9	M	549.25	158.° W.	1. black. 2. red.	1. grey. 2. brown.	1. brown.	2. yellow.	Known from the earliest period.		
Tin	white.	7.299	6	M	34.7	442.° F.	1. black. 2. yellow	1. grey. 2. fluid.	1. orange.	1. blue. 2. yellow.	d°	d°	
Arsenic	greyish white.	5.763	4	B			2. white.	1. fluid.	1. purple red.	1. red. 2. yellow.	1733	Brandt.	

TABLE OF THE PHYSICAL PROPERTIES OF THE METALS AND THEIR OXIDES, &c.

Metal.	Colour.	Sp. Gy.	Hardness.	Malleable or brittle.	Tenacity.	Fusibility.	No. and colour of Oxides.	No. and colour of Chlorides.	No. and colour of Iodides.	No. and colour of Sulphurets.	Date of discovery of the Metal.	By whom discovered.	Remarks.
Molybdena	whitish grey.	7.4		B		170°+W	1. brown black 2. blue. 3. white.			1. lead grey	1782	Hielm.	8—Does not yield to the knife, but gives no fire with steel.
Chromium.	white.	5.9	9?	B		D°	1. green. 2. brown. 3. red.				1797	Vauquelin.	9—Gives a few feeble sparks with steel.
Tungsten..	iron grey	17.5	9.	B		D°	1. brown 2. yellow				1781	M.M. D'Elhuyarts.	10—Gives plentiful lively sparks with steel.
Columbium	dark grey	5.61	8.	B		D°	1. white.				1801	Hatchett.	
Antimony .	bluish white.	6.712	6.5	B		810.° F.	1. grey 2. white. 3. yellow	1. white.	1. dark red.	1. dark grey	15th Centy.	Basil Valentine.	I have taken the numbers given by Thomson, which have not precisely the meaning of the above, but imply a scale of hardness ascending from Potassium to Steel, and each degree denoted by arbitrary figures. M denotes Malleable. B. Brittle. F. Fahrenheit's Scale.
Uranium ..	grey.	9.	8	B		170°+W	1. greyish black. 2. yellow			1. blackish brown.	1789	Klaproth.	
Cerium....	white?			B?			1. white. 2. red brown.				1804	Hisinger & Berzelius.	
Cobalt	grey.	7.7	6	B		130° W.	1. blue. 2. black.			1. yellowish white.	1733	Brandt.	
Titanium..	red?					170°+W	1. blue. 2. red. 3. white.				1781	Gregor.	
Bismuth ..	reddish white.	9.822	7	B	20.1	476.° F.	1. yellow.	1. grey.	1. orange.	1. bluish.	Mentioned by Agricola, 1520.		

TABLE OF THE PHYSICAL PROPERTIES OF THE METALS AND THEIR OXIDES, &c.

Metal.	Colour.	Sp. Gy.	Hardness.	Malleable or brittle.	Tenacity.	Fusibility.	No. and colour of Oxides.	No. and colour of Chlorides.	No. and colour of Iodides.	No. and colour of Sulphurets.	Date of discovery of the Metal.	By whom discovered.	Remarks.
Copper....	red.	8.895	7.5	M	302.26	27.° W.	1. red. 2. black.	1. white. 2. yellow	1. brown.	1. black. 2. yellow	Known earliest	from the period.	W. Wedgewood's Scale. The tenacity is measured by the weight, which a wire of the metal one-tenth of an inch diameter can support without breaking. The figures mean pounds troy.
Tellurium .	white.	6.1		B			1. yellowish white.	1. white.	1. deep brown.		1782	Muller.	
Cadmium..	white.	8.67	6	M			1. orange.				1817	Stromeyer.	
Nickel	white.	8.82	8.5	M		160°+W	1. grey. 2. black.	1. yellow.	1. greenish yellow	1. yellow	1751	Cronstadt.	
Lead......	blueish white.	11.352	5.5	M	27.7	612.° F.	1. yellow. 2 red. 3. brown.	1. white.	1. yellow.	1. blueish 2. white.	Known earliest	from the period.	
Mercury ...	white.	13.56	0	M at. — 40°			1. black. 2. red.	1. yellowish white. 2. white.	1. yellow 2. red.	1. black. 2. red.	d°	d°	
Osmium ...	black, or blueish.						1. white?				1803	Tennant.	
Silver ...	white.	10.51	7	M	187.18	22°. W.	1. dark olive.	1. grey.	1. greenish yellow.	1. black.	Known earliest	from the period.	
Palladium..	white.	11.3	9	M		170°+W	1. brown.			1. white.	1803	Wollaston.	
Rhodium...	white.	10.64	9			180°+W	1. black. 2. brown 3. red.			1. white.	d°		
Platina....	white.	21.531	9	M	274.31	170°+W	1. black. 2. brown	1. brown.		1. blueish grey 2. blueish black 3. dark grey	1741	Wood.	
Gold	yellow.	19.361	6.5	M	150.07	32° W	1. reddish brown.	1. deep yellow.		1. black.	Known earliest	from the period.	
Iridium ..	white.	18.68	9	M		180°+W				1. black.	1803	Tennant.	

FRENCH WEIGHTS AND MEASURES.

1.—Measures of length, the metre being at 32°, and the foot at 62°.

		English inches.		Mil.	Fur.	Yds.	Feet.	In.
Millimetre ..	=	.03937						
Centimetre ..	=	.39371						
Decimetre ...	=	3.93710						
Metre [*] ..	=	39.37100						
Decametre ..	=	393.71000	=	0	0	10	2	9.7
Hecatometre.	=	3937.10000	=	0	0	109	1	1.
Kilometre ..	=	39371.00000	=	0	4	213	1	10.2
Myriometre	=	393710.00000	=	6	1	156	0	6.

2.—Measures of capacity.

		Cubic inches.			English.		
				Tons.	Hogs.	Wine.	G. Pints.
Millilitre	=	.06103					
Centilitre	=	.61028					
Decilitre	=	6.10280					
Litre	=	61.02800	=	0	0	0	2.1133
Decalitre .. .	=	610.28000	=	0	0	2	5.1352
Hecatolitre ...	=	6102.80000	=	0	0	26.419	
Kilolitre.....	=	61028.00000	=	1	0	12.19	
Myriolitre..	=	610280.00000	=	10	1	58.9	

3.—Measures of Weight.

		English grains.			Avoirdupois.	
				Poun.	Oun.	Dram.
Milligramme ..	=	.0154				
Centigramme ..	=	.1544				
Decigramme ...	=	1.5444				
Gramme	=	15.4440				
Decagramme ..	=	154.4402	=	0	0	5.65
Hecatogramme	=	1544.4023	=	0	3	8.5
Kilogromme ...	=	15444.0234	=	2	3	5.
Myriogramme .	=	154440.2344	=	22	1	2.

(Henry's Chemistry, 8th edit. vol. ii. p. 530.)

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[*] Recently determined by Captain Kater to be 39,37079 inches.—(Phil. Trans. 1818, p. 109.) Henry's Chemistry, vol. ii. p. 530.

CORRESPONDENCE

BETWEEN

ENGLISH AND FOREIGN WEIGHTS AND MEASURES.

1.—English Weights and Measures.

TROY WEIGHT.

Pound.	Ounces.	Drms.	Scruples.	Grains.	Grammes.
1	= 12	= 96	= 288	= 5760	= 372.96
	1	= 8	= 24	= 480	= 31.08
		1	= 3	= 60	= 3.885
			1	= 20	= 1.295
				1	= 0.06475

AVOIRDUPOIS WEIGHT.

Pound.	Ounces.	Drms.	Grains.	Grammes.
1	= 16	= 256	= 7000.	= 453.25
	1	= 16	= 437.5	= 28.328
		1	= 27.34375	= 1.7705

MEASURES.

Gal.	Pints.	Ounces.	Drms.	Cub. Inch.	Litres.
1	= 8	= 128	= 1024	= 231.	= 3.78515
	1	= 16	= 128	= 28.375	= 0.47398
		1	= 8	= 1.8047	= 0.02957
			1	= 0.2256	= 0.00396

N.B.—The English ale-gallon contains 282 cubical inches.

The wine-gallon contains 58176 Troy grains, and the wine pint 7272 Troy grains. (Henry's Chemistry, 8th edit. vol. ii. p. 523.)

TABLE FOR REDUCING THE DEGREES OF BAUME'S HYDROMETER TO THE COMMON STANDARD.

Baume's Hydrometer for Liquids lighter than Water.

Temperature, 55° Fahrenheit, or 10° Reaumur.

Deg.		Sp. gr.	Deg.		Sp. gr.	Deg.		Sp. gr.	Deg.		Sp. gr.
10	-	1.000	18	-	942	26	-	892	34	-	847
11	-	990	19	-	935	27	-	886	35	-	842
12	-	985	20	-	928	28	-	880	36	-	837
13	-	977	21	-	922	29	-	874	37	-	832
14	-	970	22	-	915	30	-	867	38	-	827
15	-	963	23	-	909	31	-	861	39	-	822
16	-	955	24	-	903	32	-	856	40	-	817
17	-	949	25	-	897	33	-	852			

Baume's Hydrometer for Liquids heavier than Water.

Temperature, 55°, Fahrenheit, or 10° Reaumur.

Deg.		Sp. gr.	Deg.		Sp. gr.	Deg.		Sp. gr.	Deg.		Sp. gr.
0	-	1.000	21	-	1.170	42	-	1.414	63	-	1.779
3	-	1.020	24	-	1.200	45	-	1.455	66	-	1.848
6	-	1.040	27	-	1.230	48	-	1.500	69	-	1.920
9	-	1.064	30	-	1.261	51	-	1.547	72	-	2.000
12	-	1.089	33	-	1.295	54	-	1.594			
15	-	1.114	36	-	1.333	57	-	1.659			
18	-	1.140	39	-	1.373	60	-	1.717			

(Henry's Chemistry, 8th edit. vol. ii. p. 536.)

TABLE

OF THE SOLUBILITY OF SALTS IN WATER.

Names of Salts.	Solubility in 100 parts Water.	
	At 60°.	At 212°.
ACIDS.		
Arsenic	150.	
Benzoic	0.208	4.17
Boracic		2.
Camphoric	1.04	8.3
Citric	133.	200.
Gallic	8.3	66.
Mucic	0.84	1.25
Molybdic		0.1
Oxalic	50.	100.
Suberic	0.69	50.
Succinic	4.	50.
Tartaric	very soluble	
SALIFIABLE BASES.		
Barya	5.	50.
crystallized	57.	unlimited
Lime	0.2	
Potassa	very soluble	
Soda	ditto	
Strontia	0.6	
crystallized	1.9	50.
SALTS.		
Acetate of ammonia	very soluble	
barya	ditto	
lime	ditto	
magnesia	ditto	
potassa	100.	
soda	very soluble	
strontia		40.
Carbonate of ammonia	+ 50.	100.
barya	insoluble.	
lime	ditto	
magnesia	2.	
potassa	25.	83.
soda	50.	+ 100.
strontia	insoluble	
Camphorate of ammonia	1.	83.
barya	3.16	
lime	0.5	
potassa	33.	+ 33.

TABLE

OF THE SOLUBILITY OF SALTS IN WATER—*Continued.*

Name of Salts.	Solubility in 100 parts Water.	
	At 60°.	At 212°.
Citrate of soda	60.	
lime	insoluble	
Chlorate of barya	25.	+ 25.
mercury	25.	
potassa	6.	40.
soda	35.	+ 35.
Hydrochlorate of ammonia	33.	100.
barya	20.	+ 20.
lead	4.5	
lime	200.	
magnesia	100.	
mercury	5.	50.
potassa	33.	
silver	0.033	
soda	35.42	36.16
strontia	150.	unlimited
Nitrate of ammonia	50.	200.
barya	8.	25.
lime	400.	
magnesia	100.	+ 100.
potassa	14.25	100.
soda	33.	+ 100.
strontia	100.	200.
Oxalate of strontia	0.0526	
Phosphate of ammonia	25.	+ 25.
barya	0.	0.
lime	0.	0.
magnesia	6.6	
potassa	very soluble	
soda	25.	50.
strontia	0	0.
Phosphite of ammonia	50.	+ 50.
barya	0.25	
potassa	33.	+ 33.
Sulphate of ammonia	50.	100.
barya	0.002	
copper	25.	50.
iron	50.	+ 100.
lead	0.0833	
lime	0.2	0.22
magnesia	100.	133.
potassa	6.25	20.
soda	37.	125.
strontia	0.	0.02

TABLE

OF THE SOLUBILITY OF SALTS IN WATER—*Continued.*

Name of Salts.	Solubility in 100 parts Water.	
	At 60°.	At 212°.
Sulphite of ammonia	100.	
lime	0.125	
magnesia	5.	
potassa	100.	
soda	25,	100.
Saccholactate of potassa		12.
soda		20.
Sub-borate of soda (borax)	8.4	16.8
Super-sulphate of alumine & potassa (alum)	5.	133.
potassa	50.	+ 100.
Super-oxalate of potassa		10.
tartrate of potassa	1.66	3.33
Tartrate of potassa	25.	
and soda	20.	
antimony and potassa	6.6	33.

Henry's Chemistry, vol. 2, p. 552, 8th edition.

TABLE

OF SUBSTANCES SOLUBLE IN ALCOHOL.

Names of Substances.	Temperature.	100 parts alcohol dissolve.
Acetate of copper	176°	7.5
soda	176°	46.
Arsenate of potassa	do.	3.75
soda	do.	1.7
Boracic acid	do.	20.
Camphor	do.	75.
Hydrochlorate of ammonia	do.	7.
alumina	54.5°	100.
copper	176°	100.
iron	176°	100.
lime	do.	100.
magnesia	do.	547.
mercury		88.3
zinc	54.5°	100.
Nitrate of ammonia	176°	89.2
alumina	54 5°	100.
cobalt	54.5°	100.
lime		125.
potassa	176°	2.9
silver	do.	41.7
Succinic acid	do.	74.
Sugar, refined	do.	24.5
Super-oxalate of potassa		3.
Tartrate of potassa		0.04

Other substances soluble in Alcohol.—All the acids, except the sulphuric, nitric, and chloric, which decompose it, and the phosphoric, and metallic acids. Potassa, soda, and ammonia, very soluble soaps, extract, tan, volatile oils, adepoicre, resins, urea.

Substances insoluble, or very sparingly soluble, in Alcohol.—Earths; phosphoric and metallic acids; almost all sulphates and carbonates; the nitrates of lead and mercury; the chlorides of lead, silver, and soda (the last *per* Chenevix, sparingly soluble); the sub-borate of soda; the tartrate of soda and potassa, and super-tartrate of potassa; fixed oils; wax; starch; gum; caoutchouc; woody fibre; gelatine; albumen, and gluten."—(Henry's Chemistry, 8th edit. vol. 2, p. 552, &c.)

TABLE

OF INCOMPATIBLE SALTS (*).

SALTS.	INCOMPATIBLE WITH.
1. Fixed alkaline sulphates.	Nitrates of lime and magnesia, Hydrochlorates of lime and magnesia.
2. Sulphate of lime.	Alkalies, Carbonate of magnesia, Hydrochlorate of barya.
3. Alum.	Alkalies, Hydrochlorate of barya, Nitrate, hydrochlorate, carbonate of lime, Carbonate of magnesia.
4. Sulphate of magnesia.	Alkalies, Hydrochlorate of barya, Nitrate and hydrochlorate of lime.
5. Sulphate of iron.	Alkalies, Hydrochlorate of barya, Earthy carbonates.
6. Hydrochlorate of barya.	Sulphates, Alkaline carbonates, Earthy carbonates.
7. Hydrochlorate of lime.	Sulphates, except of lime, Alkaline carbonates, Carbonate of magnesia.
8. Hydrochlor. of magnesia.	Alkaline carbonates, Alkaline sulphates.
9. Nitrate of lime.	Alkaline carbonates, Carbonates of magnesia and alumina, Sulphates, except of lime.

(Henry's Chemistry, 8th edit. vol. 2, p. 560.)

(*) That is, salts which cannot exist together in solution, without mutual decomposition. This incompatibility, however, it is to be understood, exists only in solutions of a certain density.

(Henry's Chemistry, 8th edit. vol. 2, p. 560.)

COLOUR

OF PRECIPITATES THROWN DOWN FROM METALLIC SOLUTIONS, BY VARIOUS RE-AGENTS.

Metals.	Prussiated alkalies.	Tincture of galls.	Water impregnated with sulphuretted hydrogen.	Hydro-sulphurets.
Gold . . .	Yellowish white.	Solution turned green. Precipitate brown of reduced gold.	Yellow.	Yellow.
Platinum . .	No precipitate: but an orange coloured one by prussiate of mercury.	Dark green, becoming paler.	Precipitated in a metallic state.	Black. (Thenard.)
Silver . . .	White.	Yellowish brown.	Black.	Black.
Mercury .	White, changing to yellow.	Orange yellow.	Black.	Brownish black.
Palladium	Olive* Deep orange†.	. . . .	Dark brown.	Dark brown.
Rhodium .	No precipitate.	. . . .	. . . .	No precipitate.
Iridium . .	No precipitate. Colour discharged.	No precipitate. Colour of solutions discharged.		
Osmium .	. . . .	Purple, changing to deep vivid blue.		

* Chenevix. † Wollaston.

COLOUR

OF PRECIPITATES FROM METALLIC SOLUTIONS, &c. CONTINUED.

Metals.	Prussiated alkalies.	Tincture of galls.	Water impregnated with sulphuretted hydrogen.	Hydrosulphurets.
Copper . .	Bright reddish brown.	Brownish,	Black.	Black.
Iron 1 green salts	White changing to blue.	No precipitate.	Not precipitated.	Black.
Iron 2 red salts	Deep blue.	Black.		
Nickel . .	Green.	Greyish white.	Not precipitated.	Black.
Tin . . .	White.	No precipitate.	Brown.	Black.
Lead . . .	White.	White.	Black.	Black.
Zinc . . .	White.	No precipitate.	Yellow.	White.
Bismuth . .	White.	Orange.	Black.	Black.
Antimony .	White.	A white oxide merely from dilution.	Orange.	Orange.
Tellurium .	No precipitate.	Yellow.	Orange brown (Thenard.)	Blackish.
Arsenic . .	White.	Little change.	Yellow.	Yellow.
Cobalt . .	Brownish yellow.	Yellowish white.	Not precipitated.	Black.
Manganese .	Yellowish white.	No precipitate.	Not precipitated.	White.
Chrome . .	Green.	Brown.	. . .	Green.

COLOUR

OF PRECIPITATES FROM METALLIC SOLUTIONS, &c. CONTINUED.

Metals.	Prussiated alkalies.	Tinctate of galls.	Water impregnated with sulphuretted hydrogen.	Hydrosulphurets.
Molybdena .	Brown.	Deep brown.	Brown.	Reddish brown. (Thenard.)
Uranium . .	Brownish red.	Chocolate.	. . .	Brownish yellow.
Tungsten.				
Titanium . .	Grass green with a tinge of brown	Reddish brown.	Not precipitated.	Grass green.
Columbium .	Olive	Orange.	. . . .	Chocolate.
Tantalium				
Cerium . .	. . .	Yellowish.	Not precipitated. (Thenard.)	Brown, becoming deep green.
Cadmium .	White	No precipitate	Bright yellow.	Bright yellow.

(Henry's Chemistry, 8th edit. vol. ii, p. 564, et seq.)

THERMOMETERS

To reduce the degrees of one Thermometer to corresponding degrees of any other, having a different scale.

Fahrenheit's scale is the one generally adopted in England, on which the freezing point is assumed at the 32nd degree above zero, and the boiling point at 212°; the range between the two points being 180°.

On the Centigrade Thermometer, water freezes at zero, and boils at 100°. On Reaumur's, the freezing point is at zero, the boiling at 80°. On De Lisle's scale, water boils at zero, and freezes at 150°. Wedgewood's Pyrometer is only intended to measure very intense heats; its first degree corresponds with 1077° of Fahrenheit's, and each degree is equal to 130° of that scale.

To reduce Fahrenheit's degrees to the Centigrade scale, deduct 32, multiply the remainder by 5, and divide the product by 9. That is, $\frac{F-32\times 5}{9}=C.$

To reduce Centigrade degrees to Fahrenheit's, multiply by 9, divide the product by 5, and add 32 to the quotient, $\frac{C.\times 9}{5}+32=F.$

To reduce Fahrenheit's to Reaumur's, $\frac{F-32\times 4}{9}=R.$

To reduce Reaumur's to Fahrenheit's, $\frac{R\times 9}{4}+32=F.$

The range between the freezing and boiling points, on Fahrenheit's scale, is to that on De Lisle's as 6 : 5, but the order is inverted: therefore to reduce Fahrenheit's degree to De Lisle's, *under the boiling point*, $\frac{1060\ (212\times 5)-5\ F.}{6}=D.$; *above the boiling point*, $\frac{F\times 5-1060}{6}=D.$

To reduce De Lisle's degrees to Fahrenheit's, *under the boiling point*, $212-\frac{D\times 6}{5}=F.$; *above the boiling point*, $212+\frac{D\times 6}{5}=F.$

To reduce Fahrenheit's degrees to Wedgewood's, $\frac{F-1077}{130}=W.$

And, inversely, to reduce Wedgewood's to Fahrenheit's, $130\ W.+1077=F.$

Pl

Fig. 1.

Fig. 2.

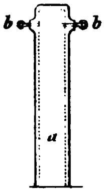


Fig. 3.

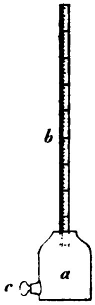
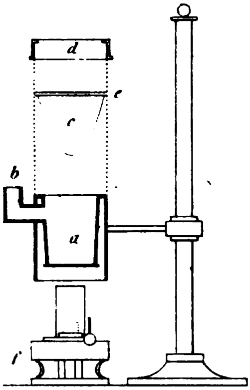


Fig. 4.

Fig. 5.



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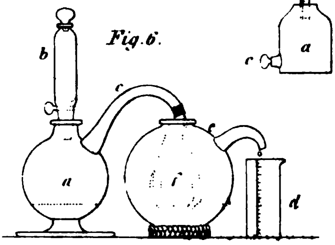


Fig. 7.

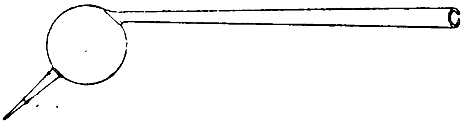


Fig. 8.

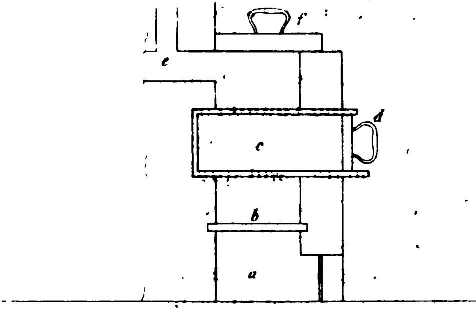


Fig. 9.

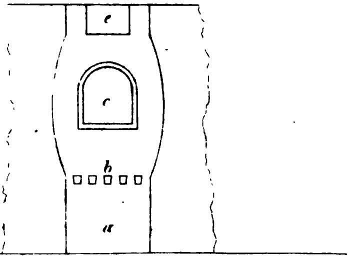
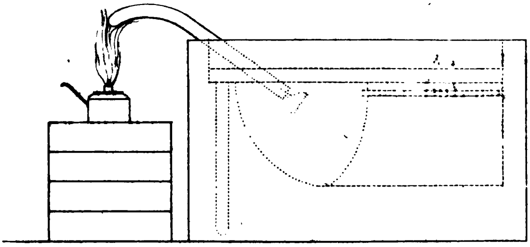


Fig. 10.



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EXPLANATION OF THE FIGURES.

PLATE I.

Fig. 1.—*An apparatus for ascertaining the quantity of carbonic acid, disengaged from a carbonate, by the action of an acid.*—The spiral tube (*a*) terminates in a perforated stopper, which is ground into the neck of the flask (*b*) so as to be perfectly air-tight. To use this apparatus, put a weighed portion of the carbonate into the bottle, and add a little water; put the acid into a separate phial, and place it, and the bottle with its tube, into one scale of a balance, and counterpoise them exactly, by weights placed in the other scale. Then pour the acid, upon the carbonate, and quickly adapt the spiral tube to its place. When the effervescence has completely ceased, ascertain the loss of weight which the scale with the apparatus has sustained, whence the quantity of carbonic acid liberated will be known. Any aqueous vapour that may rise with the gas, will be condensed in the spiral tube, and fall back into the bottle. This apparatus was invented by Mr. Pepys. (§ 169, p. 209.)

Fig. 2.—*Volta's detonating Eudiometer.*—*a*, is a very strong, graduated glass tube, *b*. *b*. brass wires, by which an electric spark is passed through the gases. (§ 28 A.)

Fig. 3.—*Dr. Hope's Eudiometer.*—*a*, a small bottle, to which the graduated tube *b*, is fitted quite tight, by grinding. Fill the bottle with a solution of sulphate of iron or other substance, according to the nature of the gas to be absorbed; then adapt the graduated tube, containing the gases, to its place, and invert the instrument so that they may ascend into the bottle, where they are to be agitated with the liquid for a short time; then hold the apparatus in its original position, and get the whole of the residual gas back into the tube, and open the stopper *c*, under water, which will rush into the bottle to fill the space left by the absorbed gas. Repeat these operations till no further diminution takes place, the amount of which may then be read off on the graduated tube. (§ 28, H.)

Fig. 4.—*An eudiometer, for ascertaining the quantity of oxygen, in atmospheric air, by Deutoxide of Azote.*

According to Mr. Dalton, when deutoxide of azote is used for the purposes of eudiometry, it is best to dilute it with some other gas, not acted on by oxygen or deutoxide of azote. "In this case, if an excess of one gas be used, the other is in a few minutes entirely taken up, and in a constant proportion—viz. 1 of oxygen to 1.7 of the deutoxide, so that $\frac{1}{2.7}$ths of the diminution are oxygen, and $\frac{1.7}{2.7}$ths deutoxide of azote." The experiment may be made over water. "Pass 100 measures of common air to 100 measures of a mixture of deutoxide of azote, with an equal volume of hydrogen or azotic gas. After standing a few minutes in the eudiometer, there will be found 144 measures. The loss 56 being divided by the common divisor 2.7, gives 21 nearly for the oxygen gas present in 100 measures of common air."—(Henry's Chemistry, vol. i. p. 392, 8th edition.)

Fig. 5.—*Apparatus for drying Precipitates by steam.* —*a*, a japanned tin vessel; *b*, its steam chimney; *c*, a thin conical glass vessel, which is inserted in *a*, as deep as to its rim *e*; *d*, a ring, which fits over the boiler *a*, and keeps the glass *c* in its place. The substance to be dried, is placed in the glass vessel, and the tin one filled with a sufficient quantity of water, which is kept at the necessary temperature, by the argand lamp *f*.

Fig. 6.—*Sir Humphry Davy's apparatus for measuring the quantity of carbonic acid in calcareous soils.* —*a*, the bottle for containing the soil; *b*, the bottle containing the acid, fitted by grinding into *a*, and furnished with a stop-cock, and a ground stopper; *c*, the bent tube of the bottle *a*, to which a flaccid bladder *f*, is connected; *d*, a graduated measure; *e*, the bottle containing the bladder. To use the instrument, a weighed portion of the soil is put into *a*; *b*, is filled with hydrochloric acid, diluted with an equal quantity of water, and fitted to its place, the stop-cock being closed. The flaccid bladder is introduced into the bottle *e*, which is then filled with water, and the graduated measure *d*, placed under its spout. When the stop-cock of *b* is turned, the acid flows into *a*, and acts upon the soil; the elastic fluid given out, passes through *c* into the bladder, and displaces a quantity of water in *e*, equal to its bulk, which is received, and its quantity shewn, by the graduated jar *d*.

Fig. 7.—*A bent tube with a bulb, for drawing off the supernatant liquid from precipitates, where it is desirable to avoid the use of filters.*—(Appendix, B.)

Figs. 8 and 9.—*Front and side section of a cupelling furnace.*—*a*, the ash-pit; *b*, the grate; *c*, the muffle; *d*, the opening for introducing the muffle; *e*, the chimney; *f*, the cover.

" The form of this furnace should be an oblong square; its dimensions being regulated by that of the muffle, which should go home to the back, its front edge lodging on the mouth of the furnace. On each side of the muffle, two inches and a half must be left, to let the fuel pass readily underneath, where there should also be a similar space. A stoke-hole must be left on the other side, but the situation of the view will not admit its being shown. Before the muffle is a projecting ledge or shelf, shewn at *e*, which is intended to support any thing that is to be put into the muffle. Two twelve-inch tiles, worked in along with the bricks, will answer this purpose."—(Henry's Chemistry, vol. i. p. 478. 8th edition, and § 62. p. 96 of this work.)

Fig. 10.—*A mercurial pneumatic trough, with a small tube and its funnel, for introducing gas, and a spirit lamp to heat the bent part of the tube, containing the substance operated on.*

This little apparatus, which has been frequently alluded to in the body of the work, is of very extensive utility, in a great variety of experiments. The tube is easily bent into the form required, and one end hermetically sealed, by means of a blow-pipe, in which the flame of the lamp is urged by a small pair of bellows.

Fig. 11.

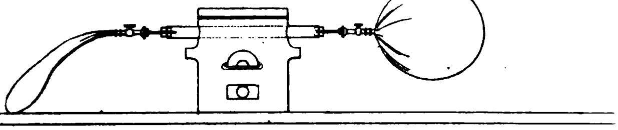


Fig. 12.

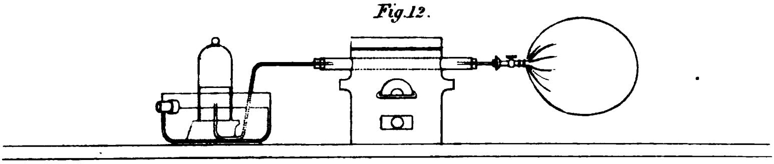


Fig. 13.

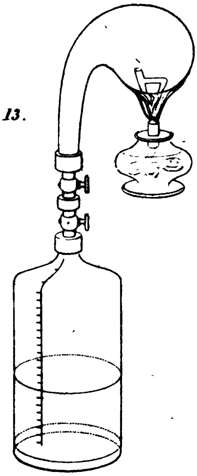
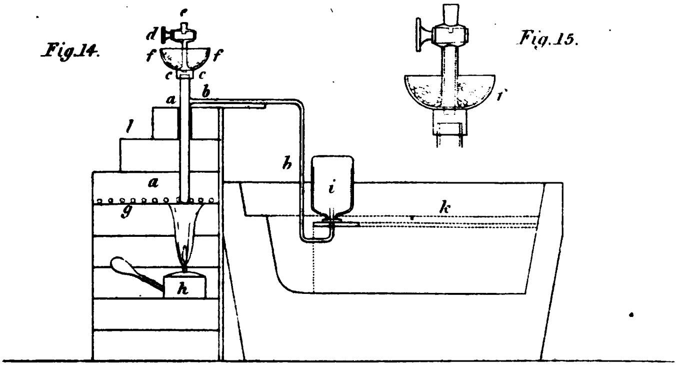


Fig. 14.

Fig. 15.



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Published by W. Phillips. London 1819.

Fig. 11.—*A small furnace, traversed by a porcelain, or metal tube, to the extremities of which, two bladders are fastened, one containing the gas, which is the subject of the experiment, the other flaccid.*

By this apparatus a gas can be brought in contact with various substances, at any temperature, incapable of fusing the tube; and by passing it backwards and forwards from one bladder to the other, the operation may be continued any length of time required. Each bladder is furnished with a stop-cock.

Fig. 12.—*An apparatus similar to the preceding, but having only one bladder; the opposite end of the porcelain tube, being connected with a small bent one of glass, which opens under an inverted receiver, over mercury.*

Fig. 13.—*Sir Humphry Davy's apparatus for ascertaining the composition of phosphoric acid.*—(§ 132. p. 170.)

Fig. 14.—*M. M. Gay Lussac and Thenard's apparatus for the analysis of vegetable and animal substances, by combustion with chlorate of potassa.*—(§ 293. p. 350.)

INDEX.

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ERRATA.

Page 5, (note) line 12 from bottom, for 75 read 7.5.
line 3 from bottom, for $\frac{5.8}{5.86}$ read $\frac{5.8}{4.86}$.
line 2 from bottom, for 5.08 read 5.6.
8, line 8, for *twelve* read *thirteen*.
13, line 3 from bottom, for *becomes* read *become*.
14, line 18, for *by acid* read *by an acid*.
line 9 from bottom, for *acid* read *oxide*.
15, for *section* read *division*.
21, line 11, for 59 read 50.
31, last line, for .4570 read .4670.
65, line 2 from bottom, for $(\frac{.6687}{2})$ read $(\frac{9687}{2})$.
74, for *section* read *division*.
111, (note) line 3, from bottom, dele *rather*.
114, line 8, for *division* read *section*.
131, (note) line 5 from bottom, for *may be dissolved* read *may not be dissolved*.
133, line 4 from bottom, for *heat the solution* read *heat them in a solution*.
156, line 5, for *equally* read *equal*.
166, for *division* read *section*.
168, line 16, for 27.38 read 12.72.
168, line 17, for 12.62 read 33.75.
171, line 6 from bottom, for 5.4125 read 5.3925.
174, line 8, for *chlorine* read *chloride*.
180, line 2, for 4 (twice) read .4.
185, line 20, for 850 read .850.
196, line 4 from bottom, for *the nitrate* read *the quantity of nitrate*.
296, line 20, for *experiment* read *experiments*.
304, for *division the third* read *division the second*.
311, for *division the fourth* read *division the third*.
323, line 12, for *calcination* read *calculation*.
360, line 20, for *these* read *those*.
376, (note) line 5, for *size* read *sine*.
404, line 9 from bottom, for *potassa* read *potassium*.
415, line 9 from bottom, dele *also*.
431, line 6 from bottom, for *strychnine* read *strychni*.